JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

VOL. 25 APRIL, 1933 No. 4

CONTENTS

All correspondence relating to the publication of papers **should be addressed to the editor, Abel Wolman, 2411 North Charles Street, Baltimore, Maryland.**

Because of the necessity for rigid economy, no reprints of articles will be furnished to contributors free of charge. Reprints may be purchased at the usual prices.

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings
Discussion of all papers is invited

Vol. 25 APRIL, 1933 No. 4

THE ADVANTAGES OF COMBINED OPERATION OF WATER AND LIGHT PLANTS

By James D. Donovan

(*Manager of Production and Distribution, Board of Public Utilities, Kansas City, Kans.*)

Either custom or legislative enactments have placed upon the governing body of the modern American city full responsibility for the proper protection of the health, life and property of its inhabitants. In carrying out this obligation it is doubtful if there is anything more important or more essential than an abundant supply of pure and wholesome water.

In performing this important governmental function, the governing bodies of many municipalities have found it expedient, economical or sometimes absolutely necessary to act in their proprietary capacity and to purchase or construct, operate and maintain their own system of water supply. Not so many years ago the business of furnishing a supply of water in most American cities was intrusted to private capital and treated as an ordinary public utility venture operating under franchise. A number of cities still obtain their public water supply in this manner, including a few cities in Kansas, but in general municipal water departments are today almost as common in the American city as municipal fire and police departments.

Undoubtedly many things have happened during the years to bring about this change, but to my mind the principal factors have

been; first, the failure of the private operating companies to furnish a supply sufficient in either quantity or quality, and second, their unwillingness or possibly their inability to obtain funds necessary for the improvement and extension of the water works in line with the needs of the municipalities. As water works men you can all recall the many deaths occurring annually from typhoid fever prior to the time that the United States Government, through its Public Health Service, made public its specification requirements of what they considered constituted a safe drinking water. Inasmuch as these requirements were made compulsory in Interstate commerce, they were promptly adopted by several states, and in putting these new regulations into effect, public health agencies in many instances condemned in total some sources of water supply, while in other instances complete re-construction of supply and treatment works was called for, necessitating in either case a considerable additional outlay of capital without much possibility of a corresponding increased return to the investor.

The business of furnishing a public water supply is one form of public utility service that never becomes a monoply in the general sense of the word for the simple reason that if rates or service are unsatisfactory the customer can still resort to the use of his own supply, either from wells or cisterns. When it was possible to obtain a water supply close to a municipality and the business consisted principally, of pumping and distribution the return to the investor in the private company was no doubt satisfactory, but with the advent of supervision of water quality by public health agencies, necessitating in many instances relocation of source of supply or extensive construction or reconstruction of treatment and filtration works without the prospect of any greatly increased revenue, this form of public utility business lost the interest of the investor and many municipalities found themselves forced, so to speak, to take over and operate the water works system of their communities as a matter of self-defense in the interest of public health. It is not my contention that this condition has applied to all privately operated water companies, but I make this as a general statement of my observations of what has usually taken place.

COMPARISON IN KANSAS CITY

As a concrete example of the relative value to an investor of investment in waterworks systems when compared with other types of

public utility investments, permit me to refer to the condition as it appears in Kansas City, Kansas. Our city owns and operates an electric plant serving some 33,000 customers and a water plant serving 28,000 customers. At the close of business December 31, 1930 (which are the last annual figures available) the electric plant represented a total investment of $4,468,313.40 and the water plant of $5,448,090.76. For the year 1930 the gross income of the electric plant was $1,855,815.98 while the gross earnings of the water plant were only $961,199.36. For this same period the net earnings of the electric plant before interest, depreciation and sinking fund requirements, was $861,307.45 while the net earnings of the water plant were only $530,650.66. The amount required for interest and sinking fund in the electric plant was $263,758.78 and in the water plant was $328,084.06. In other words, we have here an example of two public utility plants operating in the same city and serving approximately the same number of customers—one of which, the electric plant, offers to the investor earning power equal to three and one-quarter times dividend requirements, while the other, the water plant, offers to the investor a return of only one and two-thirds times the dividend requirements. Lest you might draw an erroneous conclusion from these figures and assume that the electric rate must be too high, permit me to state that the average return from all the electric energy generated during the year 1930 was only 1.82 cents per kilowatt hour which is a net return considerably below the average for electric plants of comparable size and volume of business.

ADVANTAGES OF JOINT OPERATION

The shrewd investor is interested in only one thing aside from the security of his investment and that is, how fast he can turn his dollar to increase its earning power. From this example it must be quite obvious why private operating companies are, as a rule, willing to permit a municipality to conduct a water plant business without interference while they do everything in their power to prevent a municipality from conducting an electric light plant business.

In a relatively short time the application of electricity has become so diversified and its use has increased to such an extent that the activities of the modern city of today would be practically paralyzed without it. Among the many uses to which electric power can be economically applied is that of pumping water. Hence it seems strange to me that a city which owns and operates its water plant

should delegate to a private corporation, by franchise, the right to use its streets and alleys for the purpose of transmitting electric light and power and then in turn become in many cases the largest customer of the corporation through the purchase of electric energy for water pumping, the lighting of its streets, the control of traffic, the operation of public buildings and many other governmental purposes, particularly when so many economies can be effected through the joint operation of electric plants and water plants.

There are two points of view in the discussion of the economies effected through the combined operation of water and electric plants by a municipality, one of which has to do with the total cost of service to the customer and the other with the economies effected through joint operation in construction, management and operation of such plants. Inasmuch as the former is usually a resultant of the economies obtained from the latter, it is my intention to confine the following discussion to the construction and management features only. In discussing this phase of the question, I am forced to refer in great part to the condition as it occurs in Kansas City, Kansas, as being the example with which I am most familiar.

Advantage in investment

The primary advantage of combined operation of water and electric plants is the matter of investment rquired in certain of the physical properties such as land and buildings, as well as the minor investment in certain forms of auxiliary apparatus, together with tools and miscellaneous equipment. For instance, in Kansas City we have a water intake well located within the harbor line of the Missouri River having a capacity of approximately 100 million gallons a day. This well is fitted with revolving trash screens and serves the purpose of supplying water to low pressure pumps for the settling basins of the water plant as well as circulating water for condensing purposes on the turbogenerating units of the electric plant. Adjacent to this intake well is the low pressure pumping station having a total installed capacity of motor driven centrifugal units of some 90 million gallons per day. Both of these investments are used jointly by the water and electric plants and except for the installed capacity of pumping equipment would amount to substantially the same total investment were either plant operated separately. Hence a substantial saving in fixed charges to both plants is effected through this combination.

Leading from this low pressure pumping station to the settling basins are two discharge mains that pass first through the generating room of the electric plant and thence to the settling basins and they are so placed and inter-connected that either main can be used on any one of five electric generating units with the final discharge of water being made either in the settling basins or waste back to the river as load conditions may require. This flexibility of piping arrangement would of course be unnecessary were water delivered from the low service pumping station to the settling basins for water department use only, but inasmuch as the investment necessary for this flexibility is provided by the electric plant and the major portion would have to be provided whether operated in conjunction with the water plant or otherwise, this piping arrangement does not in any way affect the ultimate investment of the water plant. Of course, some additional head is encountered because of increased friction in pumping water from the river through the more circuituous route required to serve the electric plant, and a further additional head of approximately 10 feet is encountered through the normal friction of the surface condensers, but this difference in pumping head is absorbed by the electric plant in the pro-ration of pumping cost between the two plants and hence does not effect any increase to the water plant.

The advantages of this arrangement are limited to the balance of requirements for water in the settling basins of the water plant as compared with the requirements of water for condensing purposes in the electric plant, that is, up to a point where the water required by the electric plant for condenser purposes does not exceed the amount required by the water plant for its particular purposes, the maximum of economy through this arrangement is obtained. After this point is reached, however, and the requirements for condensing water in the electric plant exceed the requirements of the water plant for water, this advantage of course commences to disappear and would eventually be lost altogether if the difference in water requirements of the two plants becomes great enough, because it is obvious that it would be expensive to pump excessive quantities of water at the higher head occurring through combined operation. However, when this point is reach, if ever, it is possible still to retain the major portion of these economies by inter-connecting certain of the electric generating units in such a manner that only such capacity will be served in combined operation as will be justified by the needs of the water plant for water.

The balance of the electric generating units could then be served through lower heads in connection with tailing pipes for river return.

In the design of condenser equipment for the electric generating units at the Kansas City electric plant we have always specified a maximum water temperature existing in the Missouri River during the summer period of 80 deg. Fahrenheit and during the past summer, because of the extremely low stage of the Missouri River, this temperature rose to as high as 87 deg. This condition, together with the relatively low steam pressure and superheat of the station and their resultant effect on the steam consumption of electric generating units, makes it necessary for us to have approximately two square feet of condenser surface for each kilowatt of electric generator rating and with 80 deg. circulating water it is necessary to have approximately nine-tenths of a gallon per minute per square foot of condenser surface or 1.8 gallons per minute per kilowatt of electric generator capacity to obtain proper conditions at the exhaust nozzle of the turbine. At the present time our normal peak load is 20,000 kilowatts, requiring circulating water for the condensers at the rate of 36,000 gallons per minute. The load factor, however, on the electric plant is such that the average requirement for condenser water represents only 60 percent of this amount or approximately 21,000 gallons per minute which is slightly in excess of the present average requirements of the water plant for water. This means that during times of peak load on the electric plant we are forced to waste a certain percent of condenser circulating water back to the river, which is the portion not required by the water plant. This waste is of water which has been pumped at a head substantially higher than would be required for the electric plant only.

I do not mean to leave the impression from the foregoing that this condition of operation has as yet reached a point that would be considered wasteful because the figures previously set out covered circulating water requirements under conditions of high river water temperature. Since the peak loads on the electric plant and water plant are not coincident, the waste of water during periods of peak load in the electric plant, which occur during the fall and winter months, is not very great because of the lower temperature of the river water during this period, which reduces the quantity required. In the warm period of the year the load on the electric plant is relatively lower and the volume of water required by the water plant is relatively greater and this condition permits the average result still to be entirely satisfactory.

The passing of this low pressure water through the surface condensers of the electric generating units has an advantage to a water plant using open settling basins, particularly during the winter season of the year, due to the fact that the temperature of the water is increased enough to prevent the formation of ice on the settling basins, and this increase in temperature also aids materially in the reaction of chemicals applied for settling and treating purposes. However, during the warmer period of the year this condition of the water appears as a disadvantage due to raising the temperature of the distributed water to a point higher than that of the river water, the ordinary increase in temperature caused from passing water through the surface condensers being between 10 and 15 degrees. A certain amount of this added temperature is again radiated in the settling basins and there is a further radiation from underground service pipes before the finished water actually reaches the customer and unless the service is in very close proximity to one of the main flow lines there is little possibility of any complaint from this source.

The foregoing advantages of combined operation of water and electric plants would not be reflected to this extent in small steam plants where the water supply is obtained from wells, nor would it be reflected in small electric plants operated with Diesel engines. However, these two types of plants would gain material benefit from combined operation by the use of single building units and much auxiliary equipment, but the extent of the advantages would depend somewhat on local conditions.

Combined operation of water and electric facilities in almost any type of plant permits the economical use of a considerable amount of electrically driven pumping equipment that would not usually prevail in separately operated units. The first cost or investment in motor-driven pumping units is far below that required for any other type of pumping unit and where they can be installed in duplicate and in close proximity to a generating station with complete duplication of service lines, they are equally as dependable as any other type of pumping equipment. In Kansas City, the high pressure pumping equipment consists of two 12½ million gallon cross-compound, condensing crank and flywheel type pumping engine and one 25 million gallon synchronous motor-driven two-stage centrifugal pump, and in the pumping of high pressure water by these units we again have the advantage of joint investment. This particular division of the water plant proper is operated on a customer basis with the electric plant. That is, the electric plant furnishes to the water plant either

steam for the operation of the high pressure steam pumping equipment or electric energy for the operation of the high pressure motor-driven equipment. Certain investments held jointly by the two plants are taken into consideration when fixing the rates charged for either steam or electric energy to the water plant. The boiler plant building, for instance, houses equipment owned jointly by the two plants and this is served by a common set of coal and ash handling equipment and other auxillary apparatus. Likewise the main engine room houses high pressure water pumping equipment as well as electric generating equipment and is served jointly by the same crane and other common facilities. If either plant were operated separately they would be required to support individually, although in a smaller way, these points of common investment which would naturally reflect some increase in their fixed operating expense.

In the Kansas City plant the 25 million gallon synchronous motor-driven unit is operated as much of the time as possible. In fact, with the single exception of a burn-out in the motor requiring rather extensive repairs, this pumping unit has been in continuous service for the past nine years, being down less than forty-eight hours total per year for inspection and checking. Our reason for operating this unit continuously would not be parallel to what may be found in other pumping stations, but to us it means a substantial saving in operating expenses through the saving of packing, pump valves, lubricating oil and other miscellaneous materials used in the operation of crank and flywheel type of pumping units. The present developments in steam turbine-driven centrifugal pumping units would not offer by any means the same comparison of economy as prevails in the Kansas City station, but, on the other hand, where the size of the prime movers in the electric plant are of a type or sufficiently large to permit design having low steam or fuel consumption per kilowatt hour, the ultimate duty obtained from a synchronous motor-driven unit is substantially the same as can be obtained from a steam turbine-driven unit of the same size and under the same conditions. The motor used on this high pressure centrifugal pump is a 2,000 H.P. motor and it has been especially designed for power factor correction. It is this feature in its continuous operation with the electric plant that enables the electric plant to furnish electric energy to the water plant at a low rate, because the electric plant benefits very materially through the operation of this motor in power factor correction on the station bus bars because excitation losses on the electric generating unit are thus reduced

to a minimum and generator capacity is maintained at a maximum with decidedly improved regulation.

It is possible for us to operate in this manner without violating any requirements or suffering any penalties from the National Board of Fire Underwriters because the boiler plant is always under pressure serving the steam requirements of the electric plant. Should electrical outage occur, the steam pumping equipment is ready to move in a moment's notice from steam supplied through the same source, hence continuous operation of the electrically driven water pumping equipment is not burdened with any standby boiler expense, the only cost to the water department when operating with steam being that which they are charged on a per thousand pounds basis.

Advantage in maintenance and operation

Another point of advantage in the combined operation of water and electric plants applies generally to all combined installations and has to do particularly with the matter of administration, superintendence, operation and maintenance of the equipment of both plants. For instance, in the Kansas City plant there is but one Chief Engineer of the Power Station who has complete supervision over both the water and electric plants and there is aso but one Operating Engineer on each shift, who in turn supervises the operation of both plants during his time on duty. In the remaining members of the routine operating crews many instances occur where employees such as firemen, helpers, coal and ash men, oilers, etc. divide their time between both plants, thus aiding materially in the reduction of operating costs in each plant. This feature of combined operation is reflected in numerous plants operating throughout Kansas. In many instances the superintendent of the water and electric plant even has some other municipal duties such as city engineer, or superintendent of a gas plant, or as in one instance to my personal knowledge, city manager, all of which has a definite bearing on the total cost of the administration of municipal government.

In the matter of maintenance, the advantage of joint operation is again reflected in the fact that the same mechanics can repair and maintain equipment of both plants. While it is true that the combined operation requires possibly a somewhat larger number of men, it is also true that were the plants to be separated it would not be possible to diminish the crews by one-half. It is our experience in

Kansas City that joint maintenance reflects very substantial savings to both plants.

Owing to the wide diversity in the character of the work performed in the distribution of water and electricity throughout a city it is not possible, in a large city at least, to effect very great economies through combined operation, although there are of course some few points of common interest involving the use particularly of unskilled labor that permits these departments to function somewhat more efficiently than if they were controlled and operated by separate maintenance organizations. In smaller municipalities not involved with labor agreements it is possible to get much more benefit from combined operation of distribution systems, because you do not encounter the customary jurisdictional arguments that are found in larger centers of population.

There is considerable advantage in the operation and maintenance of a common warehouse and storeyard at which point materials are received and disbursed for the use of either the water or the electric plant. The storeyard can be supervised and operated by a single crew and were the two plants to be separated, it is doubtful if over one-third of the help could be dispensed with because so much of the work involved in such a department is strictly routine and the excess is only measurable in the increased quantity of materials to be handled through joint operation.

A material saving is effected through joint operation in the major administration features as well as the billing and accounting departments. For instance, in Kansas City there is one Manager of Production and Distribution who is responsible for the production and distribution of both water and electricity. There is also one Manager of Collections and Accounts who is responsible for the collection and accounting features of both plants. While the state law, very properly, provides that separate sets of books and accounts must be maintained for both the water and electric plants, this does not mean that it is necessary to have a duplication of accountants. Hence in Kansas City one auditor supervises both sets of books, one cashier supervises the collections of both departments and one chief clerk supervises the billing of both departments, and were the plants to be separated it is obvious that practically all of these positions would be filled for each plant separately.

In meter reading there is further economy due to the fact that a great percent of our customers have both water and electric service and the meter readers in Kansas City are required to read both water

and electric meters. While it may take somewhat longer to read two meters on the premises of one customer, it certainly does not take twice as long, hence a substantial saving is made in this respect. These same general comments follow throughout the service and trouble departments of both plants where further duplication of employees is avoided through combined operation.

RATES AND COSTS

Water rates in Kansas City, Kansas range from 25 cents per hundred cubic feet with a $1.00 minimum for the small user, to as low as 6 cents per hundred cubic feet for consumers using more than 400,000 cubic feet of water per month. Considering the fact that these rates cover the treatment, filtration and distribution of the very difficult water encountered in the Missouri River, they are, all things considered, extremely low.

In the electric plant the average rate paid by all domestic customers during the past year was 3.7 cents per kilowatt hour, the average rate paid by all commercial customers was 3.7 cents per kilowatt hour, and the average rate paid by industrial power users was slightly over 1 cent per kilowatt hour, although several of the larger power users have earned rates for the year substantially under 1 cent per kilowatt hour.

The average cost of pumping and distributing water for the year was 11 cents per thousand gallons, this figure including interest on outstanding bonds as well as depreciation at the rate of $2\frac{3}{4}$ percent on the book value of the property. The cost of producing and distributing electric energy during the past year has averaged approximately 1.45 cents per kilowatt hour and these production costs cover all items of expense including interest on outstanding bonds as well as depreciation at an amount equal to 6 percent of the book value of the entire property.

The purpose of the foregoing figures is to furnish some tangible evidence of economy resulting from the combined operation of the Kansas City, Kansas, water and light plant. It has been conservatively estimated that were these two plants to be separated and operated under the prevailing conditions of load and equipment by separate operating organizations, the cost of producing and distributing electric energy would be increased by not less than 25 percent while the cost of pumping and distributing water would be increased by as much as 40 percent.

ORGANIZATION AND ADDITIONS

It is not the writer's contention that these few remarks cover all the advantages to be gained through joint operation of water and electric plants, nor is it contended that all the points that have been mentioned are applicable to every plant, but, generally speaking, it must be evident from the foregoing that many advantages of economical operation accrue through the joint operation of such utilities, and unless there are some extraordinary limiting physical conditions in a particular plant, these advantages greatly outweigh any disadvantages that may arise through such operation.

Since April, 1929 the water and electric plants in Kansas City, Kansas have been controlled by a board of five business men elected by the city at large for terms of four years and serving at an annual salary of $100.00 each, this board being known as the Board of Public Utilities. The Board of Public Utilities in turn employs two managers, one for production and distribution and one for collections and accounts, and these two managers direct the details of both water and electric plants.

Shortly after the organization of the Board of Public Utilities, the Board employed the firm of Burns & McDonnell, consulting engineers, Kansas City, Missouri, to survey both plants and submit to them a program of development covering some extended period in the future. As a result of this survey there is now under construction at the plant the first unit of what will eventually be a 100,000 kilowatt generating station. This initial installation is being made at a cost of approximately $1,600,000.00 and is being paid for entirely from the revenues of the electric plant and without the issuance of any bonds.

This construction program is now nearing completion and it is expected that the new unit will be in service in approximately thirty days. They consist essentially of a boiler house large enough to contain two boilers, each having a normal capacity of 150,000 pounds of steam per hour, one being installed at the present time and one to be added during the course of the coming year. These boilers will operate at a pressure of 450 pounds with 250 deg. Fahrenheit superheat and are complete with economizers, air preheaters and water wall furnace. Firing is with pulverized fuel using the unit system and boiler control and is completely automatic on what is known as the air-flow-steam-flow basis. The generator room will contain a 12,500 KVA generating unit in the initial installation and three 30,000 kilo-

watt units for future installation. The generator room is served with a 100/ton crane and is designed in size and proportion for the larger type units to be installed at later data when their need is required. Circulating water for the condenser will be obtained in this plant on the same general basis that is in vogue in the present plant and in the construction of this initial unit there has been installed (based on future requirements) two 60-inch cast iron low pressure flow lines which are at the present time connected with the old source of low pressure supply, but which will be in the future extended individually to the intake well.

This new building and equipment is being erected on new land acquired during the past year adjacent to the older generating station, the land formerly having been used by the Kansas City, Missouri, Water Department as their low pressure service intake for the Kansas City, Missouri, water supply. In the purchase of this property, in addition to the land, reservoirs and buildings, certain usable equipment was acquired, principal among which was one 50 million gallon turbine-driven low pressure pumping unit and a concrete and brick intake well in the Missouri River just below the old intake well of the Kansas plant. Both of these units of this acquired equipment have been rehabilitated and are now interconnected into the low pressure water system of the Kansas City, Kansas, plant and give to the plant an enormous reserve of capacity on an exceedingly small outlay of money.

(*Presented before the Missouri Valley Section meeting, October 29, 1931.*)

METHODS OF FINANCING FIRE PROTECTION

By Nelson A. Eckart

(General Manager and Chief Engineer, Water Department, San Francisco, Calif.)

A water works system generally has two primary functions:

(1) To supply a hygienically safe and potable water under reasonable pressure for domestic and industrial purposes and

(2) To supply water in adequate volume under reasonable pressure for extinguishing fires. The distinction between these two classes of service as they affect the layout and operations of the water works plant is essentially that the first involves the delivery of a more or less continuous supply of pure water through the system to be utilized by a large number of individual consumers in varying amounts mostly through small connections; the second involves primarily a "stand-by" service, ready to deliver a large volume of water for brief periods of time on infrequent occasions through relatively large connections at any given point in the system or simultaneously at several points.

The system must be designed and constructed with proper capacity to meet the demands of the fire protection service while at the same time adequately supplying the domestic and industrial consumers. Provision must also be made for economical expansion of the system to meet or anticipate the increasing requirements of both classes of service. The capital investment in a system capable of adequately supplying water for both classes of service to a given community must be, obviously, more than in a system laid out to supply either class of service alone. Likewise, the operating expenses of a system supplying both classes of service must be, necessarily, greater than if supplying only one or the other classes of service.

POSITION OF THE WATER WORKS

A municipality operating a water supply system is generally held to do so in a proprietary as distinguished from its governmental capacity. This applies to the municipal operation of any publicly-

owned utility, such as a municipal electric light and power plant, or a municipal street railway as well as the water supply system. All of these are primarily dependent upon revenues derived from the sale of service to cover the operating expenses and fixed charges. The sewer system, street cleaning, street repairs, police and fire departments, etc. are considered to be operated by the municipality in its governmental capacity, the expenses in connection with the operation of each of which are in general paid out of funds derived from the tax levy. Some cities maintain an auxiliary water system, separate and apart from the domestic supply, for the sole purpose of providing fire protection. The construction of such a system is generally financed out of a general bond issue or by assessment as a local improvement and operation paid for from taxation. Such a system comes clearly under the category of operation in governmental capacity.

As a municipal water works furnishes the individual consumer with water and the municipality with fire protection service it may be considered to operate in a dual capacity, i.e., proprietary as to its function in supplying water for domestic and industrial purposes and governmental as to its functions in furnishing public fire protection service. From a practical operating and accounting point of view we prefer to consider the water works as functioning purely in a proprietary capacity as a complete entity separate and apart from the rest of the municipal government, furnishing water and service to the fire department and to all other city departments just as to any individual or factory at properly-established rates. The trend of legislation relative thereto seems to be to provide for just this concept and to require that such a utility shall stand on its own bottom and pay its own way, making proper reimbursement to other municipal departments for all services rendered and in turn collecting at going rates for all service supplied to these.

There is no doubt that the dual nature of the functions of the water department above referred to is in part to blame for much of the confusion that exists in the minds of the public and of many public officials as to the obligations and responsibilities of the water works to other city departments and to the tax paying public. This and the failure to distinguish between the water user or rate payer, and the tax-payer, is in no small degree responsible for such practices as furnishing free water to city departments, diversion of surplus earnings to the general tax fund, furnishing fire service, both public and

private, without charge or at rates less than cost, and for some of the methods used in financing extensions to the system.

TAXPAYERS AND RATE PAYERS

While the title to a municipally-owned water system vests in the municipal corporation it often is the water users or rate payers and not the taxpayers who pay the cost of acquisition. Water systems are almost invariably purchased or constructed from the proceeds of bond issues which are a lien against the real property within the municipality; under the general law of most states these bonds must be redeemed within a definite period, without recourse to refunding, which latter course would be the method resorted to by any privately-owned utility. Theoretically, the redemption of these bonds should be from the tax levy in which case the general public would pay for the utility which it owns. Under these conditions it would, operating the utility in a proprietary capacity, be entitled to earn a revenue sufficient to pay all operating expenses and produce a fair return on the investment. In such a case extensions of the system would be financed from additional bond issues likewise redeemed from taxes or by direct appropriation from tax moneys and in turn the municipality would be entitled to a fair return on the additional investment thus provided. Under such a plan the municipality should charge the various city departments for water or service rendered at the going rates just as a private utility must charge its stockholders for service rendered or it must deduct from its rate base the value of the plant devoted to its municipal use and from its operating expense all costs allocated to operation for its own purposes. Practically this is not done and instead of the bonds being redeemed from taxes they are redeemed from water revenues and in addition, provision is made to finance extensions from revenues, and in some instances to produce a surplus from revenue to be turned over toward the expense of the city government. Under these conditions it will appear that the water user or rate payer is being called upon not only to pay the operating expenses, provide a depreciation reserve sufficient to maintain the system in an efficient operating condition, but at the end of forty years or so turn it over to the municipality debt free and without charge, and in the meantime bear the costs of required extensions. There are many large water consumers who pay little or no taxes to the municipality and likewise many properties on which large taxes are paid in connection with which little or no

water is used, and between these extremes are all the varying degrees of relative importance of tax and water payments.

Referring to this general subject, the Montana Public Service Commission said (*Kavanaugh vs. Town of Whitefish*, P. U. R. 1922 E, p. 208):

"To ask for rates which not only pay operating expenses, depreciation, taxes, in case of a private plant, and perhaps sacrifice taxes in the case of a municipal plant but, in addition, a sum for capital accounts, violates every principle of rate making which is grounded on the theory and usually the fact that the consumers, as a class, are not the furnishers of capital."

It seems to the writer perfectly sound in principle for a municipal system to maintain rates sufficient to produce a revenue which would provide a recognized fair return to a privately-owned utility, and apply to capital account any saving which may be effected through lower interest rates at which it can sell its bonds. Where the interest rate is low and the life of the bonds 40 to 50 years it is not unreasonable to cover interest and sinking fund charges out of water rates.

COST OF PLANT CHARGEABLE TO FIRE PROTECTION SERVICE

The reproduction cost of the portion of the physical plant chargeable to fire protection service is often considered as the difference between the reproduction cost of the existing system and the cost of a theoretical system designed to meet the requirements for domestic and industrial supply only. This method is based on the theory that the primary purpose of a water works is to supply water for domestic and industrial purposes and that the furnishing of fire protection is incidental. The California State Railroad Commission evidently had this principle in mind when it stated:

"In order to furnish adequate protection against fire it is necessary to install facilities of greater capacity than are required to supply ordinary industrial and domestic demands. Such protection is a direct benefit to the community and the excess capacity of the water system which may be deemed justified by the necessity of providing for such emergency demands can not fairly be charged against regular consumers and paid for under cover of an increase in the unit rates for water consumed for industrial or domestic purposes."

While fire protection service naturally must be considered as less essential than domestic and industrial water supply, in our present stage of development fire protection is of such necessity that if such service were for any reason not provided by the system for domestic

water supply, it would warrant the construction of an independent system solely to provide fire service. If we subscribe to this, then the reproduction cost of the portion of the physical plant devoted to fire service would be determined by estimating the costs of two separate systems, one to provide the water service and one to provide the fire protection, and using the ratio between these applied to the reproduction cost of the existing system. This seems to be the theory held by the Wisconsin Railroad Commission which said:

"Some water works men have held that the only charge which should be paid for fire protection is the actual added cost of the service above what the cost would be for a system to furnish general service only. This seems no more logical than it would be to argue that the rates for general service should be only enough to cover the excess of the operating costs of a combined plant over the operating costs of a plant to furnish adequate fire protection only. The correct principle seems rather to be that the two classes of service furnished by water utilities are coördinate; that as far as possible each should be self supporting and that when this is not the case, there is to some extent an unfair discrimination either in favor of the city which uses fire protection or in favor of the general users who use water for culinary and sanitary purposes."

In the Manual of Water Works Practice of the American Water Works Association it is suggested that the portion so chargeable may be determined most equitably by the ratio of the maximum fire demand to the total combined demand for fire and for water service, for domestic, commercial, industrial and public uses. This method recognizes the principle that the two classes of service are coördinate, it is simple in its application and probably will be found to give an answer as close to the true figures as can reasonably be expected in a problem which does not admit of any exact determination.

COSTS OF SERVICE CHARGEABLE TO FIRE PROTECTION

Whatever principle is adopted for determining the reproduction cost of the portion of the physical structures required for fire service, whether it be the "excess" cost or the "coördinated use" the same should be used in determining the operating costs chargeable to fire protection service.

In the excess cost principle it is comparatively a simple matter to go over the operating accounts of the system item by item and determine which charges are there by reason of rendering fire protection service, and these with the proportionate interest, maintenence and depreciation charges go to make up the costs of service.

In the coördinated service plan, it is helpful to visualize the system

as constructed, but providing only fire protection service. Water must be available at the sources of production, the transmission mains must be maintained, pumps must be turning over to maintain pressure and keep the distributing reservoirs filled against system leakage, hydrants must be maintained, and general administration and supervision are required. For any given system a careful analysis must be made of all of the items of operating expense, and some will be found, such as meter reading, billing and collecting, purification, etc., which may be chargeable wholly to water service, others—as hydrants, maintenance, etc., chargeable directly to fire service, but most items will be found to be in some degree chargeable to both and these charges must be fairly allocated, some upon the basis of potential demand, some on the basis of use.

DISTRIBUTION OF CHARGES

The rate schedule should be such as to produce the required revenue, and at the same time equitably distribute the burden of providing this revenue between the different classes of service, including fire protection service, and between users of the same class of service.

The standard form of schedule approved by the American Water Works Association and the New England Water Works Association is without question the most satisfactory for equitably basing the charges for domestic and industrial water consumption. These rate schedules for very practical reasons do not provide for public fire protection service charges which are left to be dealt with in such manner as may best meet the conditions peculiar to the particular community.

While it is agreed by practically every water works man and public utilities commission or other rate making body in the United States that the water user or rate payer should not be compelled to pay through the water rates the cost of providing public fire protection service, nevertheless in all but an extremely limited number of cases, a large portion if not all of this cost is so borne.

This unsatisfactory state of affairs relative to fire protection charges is the outgrowth of conditions existent in the early history of public water supply system. Frequently the furnishing of free water for fire protection and other public uses was a condition written into franchises granted to private companies for water works operation. With the acquisition of the private water works by the municipality this practice naturally was continued. New systems constructed in

other municipalities followed the practices in effect in the older utilities, loose systems of accounting made no attempt to separate the cost of operating the water system from the conduct of other city departments, and rates often were adopted solely on the basis of charges made in other cities. Practice once established is difficult to change. As a result of principles established and decisions made by many of the state regulatory bodies, it may be said that there is a tendency throughout the United States to transfer from the water rate payers to the community the cost of fire protection service. That this is far from being generally realized was well recognized by Mr. Allen Hazen in his book on *Meter Rates* when he said in reference to making a rate schedule—

"The first step after ascertaining the revenue to be raised is to deduct from it the amount that can be realized from fire service. The fair value of the fire service to the community is one thing; the amount that can actually be realized from it is another."

Reference has been made previously to several methods of allocating the costs of water service and fire protection service. Having determined the amount of revenue which should be produced by the fire protection service, it remains to determine the best method of charging for this service and distributing those charges. Public fire protection is a governmental function just as is police protection, and the public health service, and the cost thereof should be borne by the community. The burden should be distributed in proportion to the benefit received. Bearing on this problem, Edward B. Mayer, in a paper[1] presented before the Section meeting on October 29, 1930, cited various decisions of the California Railroad Commission which may be here quoted in part:

"Municipalities should pay a proper proportion of total cost of fire protection utility service * * *."

"A charge for fire protection does not necessarily vary with the quantity of water used for this purpose, but rather with the amount of protection afforded."

"The burden of a fire service rate should be borne in proportion to the benefit obtained, and the payment therefor should be closely proportioned to assessed valuation of inflammable property."

Assessed valuation of inflammable property as a basis of proportioning the burden of public fire protection, presents serious difficul-

[1] Journal, February, 1931, page 241.

ties in its application. It would require special appraisal of all improvements on real estate with respect to their inflammability, and to be logical further consideration would have to be given to the contents of the buildings both as to value and inflammability.

It is essential that the basis of assessing benefits must be most simple in its application. From this point of view the direct property tax is perhaps the most convenient and possibly is as equitable as any method of equal simplicity and convenience. Applied against all real property it provides a charge against vacant lots which has much to be said in its favor, it does discriminate against the owner who erects a fire-proof building compared to one who maintains a cheaper non-fire-proof structure or fire hazard. It may be argued that the principle of providing funds for fire protection by this method is no different than providing funds for police protection, for school purposes, for parks and playgrounds, and for any other public purpose. Why quibble over the character of property to be assessed for fire protection any more than for any other governmental function. In our cities we do not generally attempt to grade the tax on property in accordance with the value of any governmental service rendered as between improved or unimproved property, or residence or factory. Nor do we put a police tax on automobiles as apart from other property.

Approaching the problem from a different point of view, with the object of developing some other equitable basis of applying the tax, a plan suggests itself of dividing the community into different zones or districts on the basis of the fire demand capacity provided in each of the several districts, proportioning the fire protection charges between the districts and applying a uniform tax throughout each district, on the basis of property values or on a square footage basis. This plan has the merit of simplicity, in that the tax rate throughout a given district would be uniform. The number of zones need not be more than possibly four to give a fairly good range of distribution between the undeveloped and the congested value districts. In any given district the fire demand capacity would be more or less equally available throughout the district, and that capacity is equally available to each piece of property. It is clear that the system capacity in any district is not reduced because some lot is unimproved or because in the congested value district a two story structure exists on a lot adjoining a thirty story building. That two story building may present a greater potential hazard and incidentally a far greater poten-

tial demand for fire service than the thirty story fire-proof structure. It must also be considered that the two story building will probably be replaced by a modern structure, and capacity is provided for that future structure; other property in that district should not be required to carry the charges on the excess capacity provided to take care of property not improved to what may be considered the standard of the district.

The writer does not wish to be understood as advocating such a plan as against the uniform tax on real property which it is felt closely enough distributes the burden to the beneficiary. It is hoped however that discussion of the same may evoke some further thought along these lines, in the general movement toward standardization of principles.

METHOD OF CHARGING FOR PUBLIC FIRE PROTECTION

The several methods of charging for fire protection service in general use are

1. Hydrant rental
2. Charge per mile of pipe with an allowance per hydrant for maintenance.
3. Charge per inch foot of pipe distribution system with an allowance per hydrant for maintenance.

These methods are thoroughly discussed in a chapter of the Manual of Water Works Practice devoted to this subject and need not be gone into in this paper at any length.

Whichever of these methods is adopted, it is necessary, first, to determine the amount which the community is to contribute annually to the water works to pay for the cost of fire service. Subtract from this sum the annual cost of hydrant maintenance and divide the remaining amount by the number of hydrants, the number of miles of pipe, or the number of inch feet of pipe used to provide the service. If the fire protection service did not increase from year to year, the charge against the community for that service could more conveniently be billed as a lump sum annually. However, as it does increase, in order to afford a convenient and ready means of adjusting the amount of the charge to the increased service, it is necessary to choose some unit of the system, the increasing number of which units will closely correspond with the increased fire demand capacity provided and apply a charge on the unit basis.

This has led to the favorable consideration of the inch foot basis of

charging for fire protection, in the more modern schedules for fire protection service.

The cost of fire protection service should be revised at intervals of 5 to 10 years and adjustments of the charge made to correct differences which may creep in through new developments, abandonments of structures, or as the result of the failure of the unit chosen to accurately correspond to the additional protection provided.

FINANCING EXTENSIONS

A questionnaire on methods of financing water main extensions included in a paper by W. E. MacDonald of Ottawa presented at the San Francisco Convention in 1928 listed the following methods:

1. Local improvements
2. Bonds
3. Department earnings
4. Consumers
5. Guaranteeing 10 percent of cost
6. Company
7. Debenture
8. Front foot Assessment on basis of 6-inch Pipe

to which might be added by direct appropriation from municipal funds.

If the construction or acquisition of the system and subsequent extensions are financed from revenue and the schedule of rates established produces the required revenue and equitably distributes the charges to the various classes of consumers or beneficiaries, it is of no importance to distinguish between financing for fire protection service and water service. When financing is provided from earnings we may consider the following several methods:

1. Appropriation from surplus
2. Bonds
3. Debentures
4. Deposit

The method by appropriation from surplus (No. 1) is perhaps the most common for extending mains for water and fire service where the same is done from earnings, particularly where it is estimated that the revenues will immediately justify the installation. The No. 4 method which we refer to as the "Consumers' Deposit" is used in financing extensions into new subdivisions and where sufficient revenue is not in prospect to immediately warrant the extension;

under this method refund is made from the department surplus as the revenue warrants to the extent of four times the annual revenue.

Bond financing, and by this reference is had to bonds which are a general lien on all property within the municipality, is perhaps most frequently used for major extensions and improvements to the system, although sometimes used to provide for financing and accumulation of minor improvements or replacements, which may urgently be needed and beyond the ability of the water works to finance directly from surplus. In this state such bonds may be issued only after an election and upon a two-thirds majority of the votes cast. They must be redeemed usually in not more than forty years, the redemption being made serially in equal annual payments. Interest and redemption usually are paid from revenues, but such payments are in effect guaranteed from taxes. This type of financing provides usually the cheapest money, but is unsatisfactory except for the largest class of improvements on account of the red tape involved, and the uncertainty of a popular election, especially if the benefits do not apply generally throughout the city.

Debentures, where a water works has authority to issue same, provide a much more flexible method of financing all but the largest extensions. In San Francisco today we have a charter amendment before the people to be voted on in the November election, authorizing our Public Utilities Commission to borrow up to $5,000,000 on notes or certificates of indebtedness, guaranteed by the surplus revenues of the department as to principal and interest, with a maturity not to exceed twelve years—this to provide for a number of urgently needed additions and betterments.

Financing entirely from revenues means generally high water rates, particularly where development is rapid, or where the system has a large accrued depreciation without reserves, and is frowned on by the Regulatory Commissions as unfair to the rate payers. A water works must expand and it can not expand without funds. If it can not provide those funds from revenue either directly or by borrowing and refunding from revenue, resort must be had to taxation in some form or other.

The front foot assessment on the basis of 6-inch pipe cost, or approximate equivalent, provides a most convenient means for laying mains in new streets in conjunction with or simultaneously to the street improvement. The excess cost of any larger pipe installed is provided for out of department funds. This has the merit of placing

an equitable portion of the extension charge on the property benefited by the fire protection and water service afforded. The installation of the pipe, just as the improvement of the street, adds to the value of the property. In San Francisco we have given some consideration to this but have been hesitant to recommend the adoption of the method owing to the fact that up to now all pipes laid have been installed at the expense of our predecessors the Spring Valley Water Company or the Department, and it would seem to be unjust now to call upon the owners of vacant property as it is being developed to pay for the mains, when other property throughout the City has not been compelled to. Some study is being given to a plan which would provide for the assessment being made and refunded in a manner similar to the "Consumers' Deposit" method, but details have not been satisfactorily worked out.

Local improvement district method of financing while feasible is somewhat more complicated, but has a field in connection with special development. An auxiliary fire protection system in a congested value district would be a very proper subject for a special assessment district.

(Presented before the California Section meeting, October 26, 1932.)

THE MISTREATMENT OF WATER

By C. R. Knowles

(*Superintendent Water Service, Illinois Central System, Chicago, Ill.*)

The mistreatment of water covers a wide field but for convenience it may be summed up under three general heads: (1) the pollution of natural water supplies; (2) abuses in the coagulation of public supplies; (3) improper treatment of boiler waters.

The subject is so broad that it is impossible to cover it completely in a paper of this kind, therefore, the discussion will be confined largely to a summary of certain points of common interest to railway and public water utility officers.

NATURAL WATER SUPPLIES

The mistreatment of natural water supplies in its worst form is from the trade wastes discharged into streams and rivers. Trade wastes produce various objectionable effects on the water including tastes, odors, hardness and corrosion, depending on the character of the wastes. Dissolved mineral matter increases the hardness of the water, very materially increases the expense of water purification and in many cases makes it wholly unfit for industrial use. The worst examples of this form of pollution from the standpoint of industrial use are mine wastes and salt water from oil wells.

The pollution of water by mine wastes has always been a very serious problem to water works operators in coal mining territory. Thus far there seems to be no practical solution of the problem other than to avoid the use of water subject to such pollution. Rock-dusting of mines with limestone has been suggested as the most practical method of decreasing the acidity of mine water by neutralization, but it as well as other methods appear to be of doubtful value.

Although the methods followed may be efficient and economical, a water of hardness corresponding to the acid content of the mine water is the result of any form of treatment except distillation.

Pollution from mine wastes not only results from the water pumped from the mine, but is also caused by outside gob piles. These gob

piles are composed of the waste material from the mines consisting largely of pyrites and are exposed to the most favorable condition for acid formation, and if located in the water shed of a reservoir or stream they are important contributing factors toward the pollution of the water.

A stream in Kentucky became so badly polluted by mine wastes during the period of low water caused by the drought of 1930 that it was necessary to abandon the supply. The sulphuric acid content of the water was as high as 180 grains per gallon.

Salt water wasted from oil wells affected the water supply of a southern city of 50,000 people to such an extent that it was practically unfit for use. Boilers, heating systems and even coffee urns in restaurants were destroyed by this water. The salt content at times was more than 200 grains per gallon. The city was finally forced to an expenditure of more than $600,000 for the construction of a reservoir for the storage of water for use during periods of low water when the salt predominated in the river water.

According to the Manual of the American Water Works Association more than 245 water supplies widely distributed through the United States and Canada have been injuriously affected by industrial wastes of various kind. The ncessity for sound State and National legislation is strongly emphasized to adequately control pollution from industrial wastes.

IMPOUNDED SUPPLIES

The water shed is of first importance as affecting the quality of water in an impounding reservoir and is the primary factor to be considered in the selection of a reservoir site. If the water shed is subject to pollution to such an extent that the quality of the water will be materially affected, either chemically or bacteriologically, another site should be selected. In the majority of cases, however, objectionable water shed conditions may be corrected.

The most effective method of protecting the quality of an impounded water supply as affected by the water shed is to purchase the entire catchment area. This is rarely practicable on account of the expense, but in every case the water shed should be under control to the extent that gross pollution is prevented. The ownership of the reservoir site or water rights must include the right to exercise general supervision of the water shed and absolute control over all land within 500 feet of the water's edge. If this 500 foot strip is

kept well graded and sodded it will reduce the silting of the reservoir and protect the quality of the water to a large extent. The water shed should be self-draining as pools or pockets of water in the water shed or tributary streams become warm and stagnant during dry periods and are breeding places for rich cultures of organisms, and when they overflow are washed into the reservoir.

Organic growths occur in impounded water supplies under the most favorable conditions and too much care cannot be exercised in the construction and maintenance of an impounding reservoir. Practice varies somewhat as to the preparation of the reservoir itself. In every case the area below the high water contour line is cleared of trees, brush, high grass and weeds, and in most cases it is required that stumps and roots be grubbed from the ground. In more rare cases the bottom and sides of the reservoir are stripped to prevent stagnation and organic growth. The stripping of the sides and bottom of the reservoir is the most effective means of preventing growth of organic matter and is effective for periods of from five to twenty years depending on climatic and other conditions, but it is not a guarantee that no trouble will be experienced, as regardless of how much care may be followed in the construction of the reservoir it must be maintained in such a manner that objectionable organic matter cannot reach the reservoir with the flowing water from the water shed or occur through permitting algae or weeds to grow in the water. Copper sulphate is effective in controlling the growth of algae, but it is much better to prevent their formation whenever possible.

The character of the water in impounding reservoirs is often seriously affected by permitting the growth of weeds, cat-tails, water-lilies and other plants. Water-lilies, water hyacinths, etc. are strictly water plants and occur within the water itself while weeds, bullrushes and other similar growths occur around the edges and below the high water contour line when the supply in the reservoir has been partially depleted. If these growths are not removed before the reservoir is allowed to fill they will ultimately decay and materially affect the water by imparting taste and odor as well as causing excessive foaming and possibly corrosion of boilers and heating systems when the water is used for steaming purposes. These weed growths were allowed to occur in several reservoirs in Illinois during the low water stages following the recent drought, and while there has been no apparent effect on the water so far it is inevitable that these weed growths will cause a great deal of trouble when decay occurs in the

summer months. I know of one reservoir in central Illinois where fully one-half of the submerged area was allowed to grow up in weeds and cattails during the period of low water. It is not at all difficult to imagine the result when decay takes place.

PUBLIC WATER SUPPLIES

The primary purpose of the treatment and clarification of public water supplies is to improve the sanitary quality of the water, and secondarily to improve its appearance. In accomplishing these results the effect of the treatment on the water as used for industrial purposes and certain domestic uses is sometimes overlooked. In many instances the kind and amount of coagulant used results in a water harder after treatment and clarification than in its natural state.

In discussing the hardness of public water supplies as affected by methods followed in treatment and clarification it is not intended to offer any undue criticism, but rather to call attention to actual conditions as affecting the quality of the water for washing and industrial use.

The sulphate hardness of the water is increased in nearly every case where an acid coagulant is used. In the great majority of cases the total incrusting solids of the water is increased. In many instances the effect is to decrease the carbonate hardness and increase the sulphate hardness. In the case of the so-called border line waters of moderate hardness and a balanced carbonate sulphate hardness the result of the treatment is to render these waters highly corrosive when used in boilers or hot water systems.

The ill effects of this increased hardness are probably of greatest industrial consequence when the water is used in steam boilers. The effect of the increased hardness is also important in the manufacture of soft drinks, bakery products and other foods, and of even greater importance in the manufacture of paper, the textile industry and other similar processes.

The difficulty of using soap with hard water is probably the most widely known of all the ill effects of dissolved mineral matter in water. While this phase of the hardness of water is of importance in the home as affecting the sheen of Milady's hair, the family linen and the ring in the bath-tub, it is of even greater importance to commercial laundries.

Hard water will waste soap to the extent of about $1\frac{1}{3}$ pounds of

pure soap per thousand gallons of water per grain of hardness per gallon. At 11½ cents per pound for ordinary laundry soap this represents a watte of about 15 cents for each grain of hardness for every thousand gallons of water used. Soft water is of particular importance in laundry work, as in addition to the saving in soap the linens will last longer and come from the laundry softer and whiter than if hard water is used. With the use of hard water, deposits resulting from the combination of the hardness forming constituents in the water with the soap are lodged in the fiber of the cloth. It has been estimated that clothes washed in soft water have an increased life of from 25 to 100 per cent depending on the hardness of the water and the soaps or chemicals used in softening.

Among other objections to hard water for domestic use, aside from the extra cost of soap and other preparations for softening water, is the expense of installing cisterns and double pumping systems; the cost of operation; loss in fuel used in heating plants through incrustation forming on the inside of pipes of heating systems.

The question of hard water as related to public water supplies is a good deal like the weather; we talk about it a lot but rarely do anything to correct it. On the other hand, as previously stated, the treatment of city supplies frequently results in making a water harder than it was in its natural state.

EXAMPLES OF MISTREATMENT

Table 1 shows a number of analysis of public water supplies before and after treatment and clarification. For obvious reasons the names of the cities are not given and the various analyses will be indicated by numbers.

No. 1. The analysis indicates that this water has been made very much softer as there is a material reduction in the incrusting solids, a complete removal of the suspended matter and in general a very good improvement over the original raw water.

No. 2. This water shows an increase in the sulphate hardness. There has been some reduction in the silica and the suspended matter has been removed, but the incrusting solids have been increased nearly 1 grain. This water having a natural tendency toward corrosion when used in boilers has been made worse by the treatment, and the increase of one grain hardness means an additional expense of about 15 cents per thousand gallons for soap when the water is used for washing.

TABLE 1

The effect of treatment on public water supplies

(Results in parts per million)

NUMBER AND SOURCE		SILICA	OXIDES OF IRON AND ALUMINUM	CALCIUM		MAGNESIUM CARBONATE	SODIUM AND POTASSIUM				INCRUSTATION	NON-INCRUSTATION	ORGANIC MATTER	SUSPENDED MATTER
				Carbonate	Sulphate		Sulphate	Chloride	Carbonate	Nitrate				
1	R*	0.68	0.09	3.63	8.09	4.07	0.51	0.68		1.05	16.56	2.83	0.47	4.20
	T*	0.07	0.06	1.05	2.12	0.71	7.99	0.68		1.05	3.99	10.02	tr.	
2	R	0.72	0.07	0.50	2.90	0.60	1.81	0.34		tr.	4.79	2.92	0.58	1.17
	T	0.33	0.05	1.04	3.62	0.72	1.83	0.68		tr.	5.75	2.66	tr.	
3	R	2.99	0.33	0.97	2.08	0.90	3.68	0.68		tr.	7.26	5.35	0.70	2.10
	T	0.61	0.05	0.46	4.75	1.08	1.18	0.68		tr.	6.94	2.05	tr.	
4	R	0.56	0.07	3.48	2.18	0.49	0.51	0.68		0.70	6.77	2.58	0.47	3.50
	T	0.33	0.05	2.32	4.12	0.65	0.01	1.36		tr.	7.46	1.53	tr.	
5	R	1.05	0.07	1.82	2.03	0.71	0.18	0.34		tr.	5.68	2.15	1.05	6.54
	T	0.61	0.12	1.68	3.69	0.85	tr.	0.68		tr.	6.95	0.90	0.35	
6	R	0.65	0.09	8.18	1.63	0.62	2.03	2.04		tr.	11.17	4.36	tr.	1.17
	T	0.68	0.09	1.43	1.93	0.44	1.97	2.04		tr.	4.57	4.38	tr.	
7	R	1.26	0.07	1.80	0.75	0.51	0.69	0.68		tr.	4.40	1.69	tr.	5.02
	T	0.28	0.05	1.93	1.39	0.49	0.35	0.68		tr.	4.14	1.24	tr.	
8	R	0.72	0.09	7.12	8.02	5.80	12.24	2.38		tr.	21.76	15.27	0.47	4.20
	T	0.63	0.09	7.22	12.22	5.87	8.77	2.38		tr.	26.03	11.35	tr.	
9	R	1.33	0.12	7.27	7.91	5.81	11.53	2.04		tr.	22.45	14.69	0.58	3.50
	T	1.49	0.14	7.42	8.01	5.89	13.71	2.38		tr.	22.95	15.95	tr.	
10	R	0.56	0.09	1.40	None	0.26	0.35	0.68	2.79	tr.	2.31	3.95	tr.	1.17
	T	0.46	0.09	2.57	None	0.41	0.21	1.02	1.63	tr.	3.52	3.08	tr.	
11	R	0.72	0.07	3.25	1.01	0.60	1.16	0.68		tr.	5.65	2.87	0.47	4.20
	T	0.21	0.05	2.26	3.87	1.15	0.20	1.02		tr.	7.53	1.18	tr.	
12	R	0.21	0.10	0.85	0.28	0.25	0.56	1.02		tr.	1.68	2.06	0.35	2.10
	T	0.44	0.07	0.88	1.54	0.21	tr.	1.02		tr.	3.15	1.17	tr.	
13	R	0.77	0.09	3.70	1.03	0.37	1.28	1.36		tr.	5.97	3.73	0.47	4.20
	T	0.26	0.12	1.05	2.46	0.83	0.28	1.70		0.58	4.70	2.42	tr.	

* R, raw and unclarified; T, treated and clarified.

No. 3. While there has been a slight reduction in the total hardness of this water, the sulphates have increased, making it more corrosive when used for steaming purposes. The scale formed by the treated water will be more dense and therefore more objectionable in character than that formed by the raw water.

No. 4. The treatment and clarification of this water has also increased its hardness. The carbonate hardness has been reduced, but the sulphate hardness has been nearly doubled, increasing the objection to it as a boiler water. In this case the increased demand for soap is only about 10 cents per 1,000 gallons, but the reduction in carbonate hardness and increase in sulphates has increased the tendency toward corrosion.

No. 5. A case where the sulphate hardness has been increased one and two-third grains and a slight reduction made in the carbonate hardness, with an increase in total hardness of one and one-third grains. There has been a reduction in the amount of silica, but there still is a small amount of suspended matter present. This water has been made much worse for boiler purposes, and the increased soap demand over the raw water is about 20 cents per thousand.

No. 6. The total hardness has been materially reduced, thus making it a much better water for general use. The treatment has reduced the soap demand, but the increased sulphate ratio has made the water corrosive when used for steaming purposes.

No. 7. This water shows a slight decrease in the total hardness, an increase in sulphate hardness and a decided reduction in silica and complete elimination of suspended matter with but little change in the character of the water.

No. 8. This treatment shows the complete elimination of suspended matter, but a very decided increase in the sulphate hardness amounting to more than 4 grains. The soap demand per thousand gallons has been increased about 60 cents. This is a hard water in its natural state and has been made very much worse by treatment. The formation of a heavy dense scale will follow its use in boilers with possible corrosion.

No. 9. This water shows a complete suspended matter elimination with a slight increase in sulphate hardness. The treatment has had but little effect upon its general character which is bad.

No. 10. This water shows a suspended matter elimination and a slight decrease in the sodium and potassium carbonate content. The total hardness has increased approximately 1.2 grains.

No. 11. This water shows a reduction of 1 grain carbonate hardness and an increase of nearly 3 grains sulphate hardness, the total hardness being nearly 2 grains greater in the treated water than in the raw river water. The soap demand has been increased about 30 cents per thousand gallons, and the water has been made unfit for boiler use without further treatment.

No. 12. This analysis illustrates how a water almost ideal for boilers in its natural state can be made unfit for use by treatment and clarification. The sulphate hardness has been increased more than 500 per cent which in the presence of the extremely low carbonate content causes the water to be highly corrosive when used in boilers and heating plants. Its use in locomotive boilers necessitates corrective treatment to prevent damage.

No. 13. The total hardness of this water has been decreased, but the sulphate hardness has been more than doubled with the result that the water is corrosive when used in boilers.

These samples were collected at random and no attempt made to select waters known to be affected adversely by the coagulant used.

Eight of the thirteen samples show that the total hardness has been increased and eleven samples show an increase in the sulphate hardness. In one case the sulphate hardness has been increased more than 4 grains with practically no decrease in the carbonate hardness. In another case an excellent boiler water before treatment has been made unfit for use by the process followed in the clarification of the water. In this particular case an enormous amount of damage is done to boilers and heating systems through the use of this water, while a railroad using the water in locomotives in addition to paying a high price for the water is put to an additional expense of several thousand dollars per year to prevent damage to locomotives using the water.

The cost of hard waters used in locomotive boilers is 13 cents per pound for every pound of incrusting solids allowed to enter the boiler.

The cost of additional soap used on account of hard water has been given as approximately 15 cents per 1,000 gallons per grain of hardness per gallon.

No rule can be given for determining the cost of water as used in heating systems and other industries through corrosion, scale formation and effect on manufacturing processes, but there is no question that the cost is enormous and would in almost every case justify the treatment of the water.

Gale S. Stout writing in the December, 1924 issue of THE JOURNAL states that there would be a saving of a quarter of a million dollars on fuel alone if the water of San Francisco were free from hardening salt in the water. John C. White writing in the November, 1925, JOURNAL states that figures prepared on the construction of a municipal softener at Madison, Wis., at a cost of $125,000 and an annual cost of $38,225 for operation, would effect a saving of $174,429 per year.

Although it may not be practical to suggest the softening of all public water supplies at this time, it would appear that more serious attention should be given the selection of the chemicals used and methods followed in coagulation in an effort to avoid increasing the hardness.

BOILER WATER SUPPLIES

The principle governing the proper operation of complete softening plants for the treatment of boiler waters has become so well established that instances are extremely rare where the term "mistreated" can be applied to the water produced by these plants.

This is not the case, however, with the treatment of water within the boiler itself by compound and other chemicals. Various nostrums sometimes parading under fanciful names are being used to overcome trouble from bad waters. Unfortunately it seems that almost anything that is done to a bad water tends to improve its condition. Therefore, even the worst of quack preparations offered for the treatment of water seems to have some beneficial effects, although some of the benefits are very slight and temporary in effect.

Because of its low price carbonate of soda or soda ash it the most common ingredient used in boiler compounds although the ingredients in the compounds offered range from tomato juice to rare or little known substances from distant countries. Many of the compounds have as their principal ingredient water, samples showing a water content of as high as 99 per cent water.

Compounds have their place in boiler water treatment, but their use should be confined to waters of moderate hardness or in such cases where the quantity of water treated would not justify a more expensive method of treatment. If a compound is used its composition should be based upon a chemical analysis of the water. Each individual water problem is a study in itself and unless the compound is designed to fit each particular water condition, satisfactory results should not be expected.

In many cases the mistreatment of water through the improper use of boiler compound is due to the theory that if the right kind of chemical or combination of chemicals can be found and applied to the water of a boiler all troubles would be over. Unfortunately for this theory waters vary in hardness, and the rate of evaporation in boilers and boiler pressure is also subject to variation. Therefore, the selection and application of the treatment must be adapted to existing conditions.

Boiler compound should be used only under the advice of a competent chemist or water engineer, and only after a thorough investigation has been made of all conditions surrounding the use of the objectionable water.

The compound should be used in correct amounts and preferably fed to the water automatically as it is delivered to the storage tank or to the boiler. The application of the compound should be checked frequently by examination of the water both before and after it enters the boiler. The same general supervision should be given compound treatment as with complete treatment in a water softening plant.

Compounds have their limitations in the treatment of boiler waters, but if their use is kept within the range of their effectiveness and the proper compound selected for the purpose, satisfactory results will be obtained. It must be remembered, however, that compound treatment requires the same consistent, intelligent supervision as that required by any other form of boiler water treatment.

(Presented before the Illinois Section meeting, April 13, 1932.)

DISCUSSION

C. H. Christman (National Aluminate Corporation, Chicago, Ill): Most of us who deal with water are prone to feel that our water supply is as good as it can be made. Our efforts are directed to its care and it is continually under our supervision. The opportunity does not come to all alike, to visit the many water systems operating in all sections of this country, to observe first hand the problems which are being faced and the solutions which have been evolved. The chance for comparison between supplies has in some instances been much greater than in others.

Standards have been established by the United States Public Health Service which are the pattern for plant operators and represent the minimum that should be striven for. The aggressive and

alert superintendent is always seeking to surpass these standards and takes a justifiable pride in reaching his own goal. These include a bacteriologically safe water, which is sparkling clear, free from taste and odor as well as low in color, and in a few instances here in Illinois, softer than the original water supply.

In the preparation of such a water, the usual procedure involves the use of alum, an acid coagulant. The use of lead piping for carrying alum solutions is just an indication of its corrosive character. The effect of this acid coagulant on reaching the main body of water is in its reaction with alkalinity to produce aluminum hydrate, the floc which acts to clarify the raw water. Observations of the treatment used throughout the middle west indicate the prevalent use of lime in conjunction with alum. This lime adds alkalinity with which the alum can react, but in addition it has added hardness to the water supply. The net effect of the alum lime treatment is that many of these waters are harder after treatment than before. Now the present trend in the newly constructed plants is to take advantage of the purifying action that accompanies water softening. The number of such plants is growing very rapidly, and current reports on new plants deal almost entirely with softening plants. The trend is to get softer water, not to make it harder. The important fact to consider is that the procuring of soft water is being made for the benefit of the every day water consumer, the householder. Industry has had to face the matter of hard water and has equipped itself adequately for this task. Now such opportunities are being demanded by the citizen.

Each superintendent may well ask himself the question, "Can my water supply be made softer so that my customers will need to spend less in the operation of his home? What must I do to take steps in the right direction? And having made an improvement in this respect, why should not I tell them when they receive their water bill that this saving has been made for them?"

Without question there are many present supplies that would be vastly improved by a change from straight coagulation to softening. Of course, there are plant changes required which involve capital expenditures. Can these be made now with the attendant prospect of giving some employment and securing therefrom a greater economy for the future?

Again there are plants where the gain to be made by conversion to softening is not so great. The possibility for improvement still is

possible in such instances. There is an alkaline coagulant available now, whereas ten years ago it was unheard of. So many advances have been made that this material costs only 5 percent of what it did when first offered for water coagulation.

This alkaline coagulant, sodium aluminate, may be used with alum where straight clarification is practiced or it may be used with lime and soda ash where softening is demanded. It works in acid and alkaline conditions. Being an alkaline material, additional alkali such as lime is not necessary when it is used in conjunction with alum. Containing alumina, it makes it possible to reduce the amount of alum required. Thus it acts in a twofold manner the net effect of which is to produce results with a softer water as the end product.

In 1931 more than 92 billion gallons of water were treated with sodium aluminate under the supervision of our Water Service Engineers. As an example of what has occurred, we may cite a plant which used 2.5 grains of alum for coagulation of a water taken from a reservoir then in use for two years. Considerable decayed vegetation had found its way into this supply. This condition may be the immediate problem of others. Upon changing the treatment in this plant, it was found that with sodium aluminate to the extent of only 0.25 grain per gallon, the alum dose was reducable from the high dose of 2.5 to 0.25 grains and with an improvement in results. While this change is very remarkable and was gratefully received by the Water Department, the idea of improvement had so infected the Superintendent that he next authorized a change which brought his plant in line with the present trend, that of softening his water. Where sodium aluminate had been effective in handling coagulation in connection with alum, it is now serving equally well as the coagulant in the softening reactions.

In city water softening, there is complete justification for sodium aluminate coagulation. The principal motive is the reduction of hardness, and, with sodium aluminate as the alkaline coagulant, each step used is toward the production of a softer water. Either iron sulfate or alum will harden the water and increase the amount of lime used. One of the immediate observations of anyone starting to soften water without sodium aluminate coagulation is the delayed reactions. In addition there is poorer coagulation, slower settling, and higher alkalinities. Some improvement can be made by increasing the lime to an excess which is usually carried above 50 parts by operators. This involves the use of extra lime and then requires

excess carbonation for its removal. Too often, filter sand is badly incrusted in such plants. To illustrate the workings of sodium aluminate in such conditions, the following data will prove enlightening. The plant in question treats an aerated well water, which contains iron, with lime and soda ash. The mixing is ample and precipitated sludge is removed with a Dorr clarifier. Carbonation follows and the water is then filtered. The following analyses indicate what is happening at each stage in the treatment, in p.p.m.:

	TOTAL HARDNESS	P ALKALINITY	MO ALKALINITY	Mg	PERM. HARDNESS	CO_2
Raw water	820	0	383	70	437	38
From mixing tank	236	101	159	38	77	
From Dorr	222	84	130	33	92	
From carbonator	205	56	114	34	91	
From filter effluent	164	26	56	34	108	

To demonstrate the value of sodium aluminate is such an operation, a gallon sample of water leaving the mixer was dosed with 1 grain of sodium aluminate and stirred 3 minutes. Coagulation was markedly improved. To illustrate the water so prepared will be compared both with the original water and the water which had been carbonated and filtered.

	TOTAL HARDNESS	P ALKALINITY	MO ALKALINITY	Mg	PERM. HARDNESS
Original water from mixer	236	101	159	38	77
Same water plus 1 grain sodium aluminate	156	43	75	24	71
Filtered water after carbonation	164	26	56	34	108

The function of sodium aluminate was that of coagulation and the removal of the complex magnesium salt formed. Note the reduction of both alkalinities and magnesium, a gross reduction of 80 parts of hardness, 84 parts of total alkalinity, 34 parts of calcium carbonate 14 parts of magnesium and 6 parts of non-carbonate hardness with only 1 grain of dry sodium aluminate. In addition to this effect, observe the decreased need for carbonation for there are 32 parts less of caustic alkalinity to remove, a decrease in itself of 75 percent. Finally, the data show the presence of serious sand incrustation

and the possibility of undersized carbonating equipment. With less work for this unit, its function may be admirably corrected by sodium aluminate coagulation just as this was effected in Hinsdale, Illinois, where sodium aluminate has been a standard part of the treatment ever since it effectually remade that plant in 1928.

WATER SOFTENING AT BEVERLY HILLS

By John L. Perhab and Arthur Taylor

(*Superintendent of Treatment Plants*), (*Engineer and Manager*)

(*Water Department, Beverly Hills, Calif.*)

Softening of the municipal water was in fact a secondary consideration in Beverly Hills when the matter of rectifying the supply was undertaken in 1927.

The water was unusually high in H_2S and iron, the food supply for prolific and persistent growths throughout the system of crenothrix and beggiatoa. Filtration was the only solution of the attendant troubles: bad tastes and odors which developed through the decomposition of those algae.

Along with rapid sand filtration, it was not a costly matter to extend the plant designs to provide for lime softening.

Plant No. 1 was completed May, 1928, and Plant No. 2 May, 1931. On two gallons per square foot filtration rate, Plant No. 1 has 10 million gallons daily capacity in all elements except filters, which at present are only 5 million gallons daily. Plant No. 2 has 3 million gallons daily normal capacity.

Both plants are of somewhat similar and conventional design except that aeration on account of the sulphur water is carried out in enclosed rooms with force draft and high towers to carry off fumes.

Both plants were designed by and built under the supervision of Salisbury, Bradshaw and Taylor, Consulting Engineers.

The treatment process briefly is as follows: The influent supply pumps from the source through Sacramento type spray nozzles onto a practically level concrete floor collecting at the low side into a flume which leads to the first battery of circular mixing chambers with variable speed control. Hydrated lime and two-thirds of the coagulant (alum or ferric chloride) are applied at the entrance of the first of the primary mixing chambers. After 15 minutes agitation the solution passes into a channel at one side of the clarifier of 45 minutes retention, thence over a weir on the opposite side where it is routed to the battery of secondary mixing chambers, losing about 80 to 85 percent of the precipitate in passage through the clarifier. The re-

maining dose of alum is applied here. When ferric chloride is used, the entire dose is applied at the primary mixing chambers.

Ammonia and chlorine application is made at these secondary mixing chambers, the ammonia being applied one chamber ahead of chlorine. From this series of agitators the water passes into the sedimentation basin which is the rectangular around-the-end-baffle type without cross baffling. The retention period is 6 hours.

Boxed in at the end of the baffle CO_2 gas is applied through a perforated pipe grid system. This timber-built chamber is so constructed that the water enters over the top and discharges at the bottom and all agitation is confined within its walls thereby not interfering with or causing any disturbance in the settling basin, and thus allowing a portion of the final settling to take place after recarbonization.

From the sedimentation basins, the water passes via flume to the filters which are more or less of conventional standard. Both air and gravity water wash are provided and also wash water reclamation.

SOFTENING

As stated before, softening of the water supply was not the first consideration; however, it has become an important feature of the City's waterworks.

The wells from which the water is pumped vary in total hardness, as Ca Co_3, from 40 to 390 p.p.m. Therefore, the different combinations of waters from these wells require vastly different chemical doses to produce a uniform plant effluent.

The hydrated lime, containing a guaranteed 97 percent calcium hydroxide, applied by means of dry feeders, reduces the hardness $15\frac{1}{2}$ p.p.m. for each one grain per gallon of lime. In conjunction with lime, 0.5 grain per gallon of alum is used as the coagulant at Plant No. 1, while at Plant No. 2, 0.25 grain per gallon of ferric chloride has been found to be a more efficient coagulating medium than alum. It is apparent that this heavier compound causes better sedimentation and lengthens filter runs.

Lime is delivered in 50 pound paper bags for $13.75 per ton. Fifty cents more conveys it to the chemical storage room. In this hydrate state it is not the cheapest vehicle for softening, but its convenience of handling has somewhat held back the plans for converting to the use of the cheaper quick lime. However, in time that plan will be carried out.

At Plant No. 2 sludge disposal is made into a large storm drain which fortunately is of sufficient grade and runs enough natural flow to carry off the precipitate. Plant No. 2 discharges the sludge into a sump which in turn through regulated flow discharges into the sanitary sewer.

It is hoped that some day the sludge will become a profitable by-product. It is an excellent sweetener for some soil and a small quantity mixed with hard clay soils makes them very workable. Perhaps a simple refining process may result in its reclamation for calcimine, tooth powder, or possibly recalcining.

VALUE OF SOFTENING

The raw water with average hardness as $CaCO_3$ of 240 p.p.m. well qualifies as a hard water. By the application of approximately 6 grains per gallon of lime, the hardness is reduced to 130 p.p.m., which is appreciably noticeable to one using soap as a fairly soft water.

Many consumers have advised us of the fact that considerable soap saving resulted from the softening municipal supply. It is not a far stretch of mathematics and chemistry to show that the soap saving to consumers more than compensates for the lime treatment or softening costs.

The total treatment cost for the fiscal year ending June 30, 1932, was 1.73 cents per 100 cubic feet at Plant No. 1, and 1.40 cents at Plant No. 2. Of this cost 55.1 per cent was labor, 31.7 percent chemicals and 13.2 percent other costs. Of the total chemicals cost, 73 percent was lime for softening, and the balance coagulants, chlorine and ammonia.

Operating at 4.6 m.g.d. average for the combined plants, or about half capacity, it is apparent that the unit cost will greatly decrease as the plants approach capacity, for virtually no additional labor will be required.

It is a simple matter to increase the lime dosage to produce a 100 or even 50 p.p.m. effluent, but in the case of Beverly Hills where the water consumptiom averages 260 and reaches 500 gallons per capita per day on hot summer days, with such a large percent of that consumption used for the large yard sprinkling, it makes the premium too high on that part that is used indoors for cleansing, washing and industry.

OTHER BENEFITS OF SOFTENING

Pipe corrosion has been reduced greatly through softening as well as through the control of pH which is afforded through lime treatment. The prolonged life of steel mains and house plumbing will effect great saving to the City and property owners.

Hot water heaters and piping have a much extended life with the use of the softened water. Plumbers have commented on this fact.

Many consumers, both domestic and commercial, have given up the use of private softening plants.

The harmful features of the iron content of the raw water have largely been eliminated through the lime softening process.

More palatable taste to the water due to softening and recarbonizing, along with the elimination of taste and odors through filtration, brought about a tremendous reduction in the sale of bottled water. A census of consumers, obtained by placing questionnaires on the water bills, showed a saving in bottled water purchase far greater than entire cost of plant operation.

(Presented before the California Section meeting, October 26, 1932.)

THE DESIGN AND CONSTRUCTION OF THE WEST SEATTLE RESERVOIR

By Samuel De Moss

(*Structural Designer, City Engineer's Office, Seattle, Wash.*)

A reservoir dug in the ground with an earth embankment is one of the oldest and simplest forms of engineering construction. In spite of this fact, failures of various sorts in earth reservoirs have been all too common, and due to their very location, a catastrophe of shocking magnitude is not infrequently the result.

This paper presents a record of the design and construction of a structure of fairly large size and capacity, the details of which the writer believes should be of interest to the profession, especially since they represent the general practice of a large municipality over a period of a number of years.

In general four considerations obviously govern any reservoir design. The side walls, if constructed in embankment, should be stable. Absolute water tightness must be attained. There must be a complete, simple and easy control of the inflow and outflow of water. Circulation should be provided within the reservoir itself.

The City of Seattle has just completed a new 70,000,000-gallon reservoir designed for intermediate service, which is to be operated in conjunction with two newly constructed low service tanks. This combination of reservoir and tanks is situated on a tract of land located in the southern part of the City, near 5th Avenue Southwest and West Cloverdale Street. It will meet the increasing needs of the large residential section of West Seattle, as well as the growing demands of a big industrial district. This industrial district comprises the Duwamish Flat, Harbor Island, and the territory bordering on the shore of Elliott Bay directly across from the main business section of the City.

In this area are located the Fisher Flouring Mills, the Ford Plant, the Fisher Body Company and other large industries. There are also large tracts of vacant property capable of industrial development. With the completion of this project the City will be in a position to furnish industrial water in large quantities for many years to come.

The West Seattle district necessitates the high, intermediate and low service reservoirs. Prior to the construction of the new reservoir, the district was fed by means of a 24-inch main from Low Service Beacon Hill Reservoir several miles away (overflow elevation, 316). To supply the high service needs, a pumping plant had been constructed at 5th Avenue Southwest and Kenyon Street, pumping into a 500,000 gallon elevated tank located at 36th Avenue Southwest and West Myrtle Street (overflow elevation 575). As the new reservoir is a hundred feet higher than Beacon Hill, a hundred feet of pumping head will be saved.

The low service was supplied from a 1,400,000 gallon tank (overflow elevation 316), located at 38th Avenue Southwest and West Barton Street, also filled from the pumping station on Kenyon Street. The new reservoir, being intermediate, will eliminate all pumping for low service.

The reservoir is constructed in cut and fill with sides and bottom paved with concrete slabs. It is designed for a capacity of 68,300,000 gallons. The shape is trapezoidal in plan which form was dictated to a great extent by the topography.

The general dimensions are as follows:

	feet
Length at top of concrete lining	855
Widths, larger and short ends respectively	705 and 530
Elevation of bottom	410
Top of berm	432
Minimum depth of water to lip of overflow	20
Maximum depth, measured at washout	22.5±

The reservoir is supplied by means of a 48-inch pipe line, with a carrying capacity of 30,000,000 gallons per day. The control takes place in a valve house 22 by 36 feet, situated at the south end of the reservoir, which end will later be the common wall between the present and a future unit. From the valve control house the supply is fed into the basin by a 42-inch line. Provision is also made to discharge to a future pump station for high service. To take care of future development a "Y" was installed to care for an additional 48-inch line as well as a 42-inch steel inlet pipe into a future basin. All large valves are of standard Chapman make equipped with floor stands and are motor operated. The house is of concrete throughout with steel sash and metal doors and is finished with white sand and cement.

The 42 inlet, which will also serve as an outlet, was made by bring-

ing the pipe into the reservoir with the bottom on the level with the reservoir floor. Special care was taken to prevent leakage through the berm along the pipe. The pipe through the reservoir berm was encased in concrete as far as the dirt line of the inside slope. Concrete was then poured around the balance of the pipe within the reservoir itself to form a box section which was flanged on the level of the lining. Copper seals between the lining and the flanges provide a water-tight joint and prevent any leakage through the berm. A short transition was introduced from the end of the circular to the square section, at which was placed a conventional steel grating, operating in a slot.

The overflow was designed to care for 30,000,000 gallons daily and discharges through 6,000 feet of 24- and 30-inch pipe into the Duwamish River.

The overflow consists of a weir 40 feet in length. The bottom is semicircular and sloping; the diameter varying from 2 feet at the small end to 3 feet at the large. A transition in the concrete section is made to suit the 24-inch pipe. The water is thus taken away evenly and at the given required rate. The top of the weir is covered with 8 sections of removable grating of varying widths.

CONSTRUCTION

Prior to calling for bids, drillings were made at several of the high points to determine the character of the excavation. The log indicated pure sand, overlying clay and hard pan. All surface soil was required to be stripped over these sections carrying fill. All rocks and stones over 4 inches in diameter were removed. Material for fills was spread in 4 inch layers and each layer thoroughly rolled with ten ton road rollers, the rollers passing at least 4 times over the area, or until thoroughly compacted. The contractor's method of handling the filled material is of interest. As we have said, a part of the excavation consisted of hard pan. This broke up into lumps and was consequently difficult to roll. A sheep's foot roller with a spreader in front was pulled over the freshly dumped earth by tractor. The spreader distributed the material into uniform layers of required thickness while the sheep's foot broke up the lumps and at the same time effected considerable consolidation. Much less rolling was required and better compacting obtained. Slopes of the embankment against which the concrete was to be poured were rolled 6 inches wider than the required cross section. These slopes were cut back

to the required grade just before concreting. Berms were made 20 feet wide on the two side walls and one end wall. The berm of the other end was intended as a party wall for a future unit and was made 40 feet in width.

Slopes were 2:1 and 3:1 inside and outside respectively. Outside slopes will be dressed later to line and grade, after which they will be covered with 4 inches of soil selected from that removed in the surface stripping. This area will be sown to a mixture of white clover and Italian rye grass in equal parts, using one pound of seed to each 200 square feet of surface.

Concrete lining was composed of sections 20 feet square except on the intersection of the slopes and the floor and corners. These were laid on ribs 8 inches wide and 4 inches deep at each joint. These ribs were formed by headers placed on each side and carefully set to line and grade to secure an even and flat surface for slab bearing. Any inequalities in the surface of the rib were rectified by plastering with mortar. After the concrete had set the headers were pulled and the space was filled and tamped.

The concrete slabs were 6 inches thick with an inch topping, making 7 inches in all. Before pouring these slabs, the ribs were mopped with asphalt upon which was placed a copper strip crimped at the center with edges turned at an angle of 90° to engage the concrete. Five-eighth's inch joints were left between slabs. This space was filled with hot asphalt, the strips being pulled just before filling. All joints were soldered and a special stamped piece was used at all intersections.

It is interesting to note that *no* reinforcing was used in the slabs. This is contrary to practice in some other cities, but experience has shown in the design of previous reservoirs here in the City that no cracks or defects developed which would warrant the added expense, provided, however, that the concrete be well mixed and properly placed. Special care was taken in the preparation of the subgrade, especially where the bottom was over a filled area. It has also been noted from the observation of pavements in Seattle that with a well compacted and uniform subgrade, there was little or no difference as far as cracking was concerned, with or without reinforcement.

Another feature of interest is the fact that no underdrain system was used. It was thought that in the case of a possible seepage leak, the damage, if any, would be local only. In case of a general underdrain grillage, considerable washing might result and whole areas

undermined, causing general settlement and consequent cracking, if not ultimate failure of the entire structure.

The concrete lining was composed of a 1:5 mix by weight. Concrete was mixed on the spot and deposited by means of bottom dump buckets. The side slopes were concreted in a similar manner to slopes of the Government Kittitas Canal in the Yakima Valley, where this method was first used.

One of the chief difficulties in reservoir construction has been that of obtaining a concrete sufficiently plastic to be watertight and at the same time to stand on the side slope.

To meet this difficulty a device which served both as a working platform and as a form was used. This consisted of a steel panel 20 feet long and approximately 4 feet wide, supported by a steel truss, which in turn rested on headers set on either side of the panel to be concreted. Attached to the truss was a platform upon which the concrete was chuted. From this platform it was shoveled and tamped behind the form. As the form was filled the whole device was raised up the slope and the operation repeated. The concrete near the bottom of the form had received sufficient set to maintain itself on the slope.

Another interesting feature of the concreting was the chuting. The chutes consisted of a series of hinged sections each 3 or 4 feet long, supported by a single truss. This truss was equipped with wheels at the top and bottom and could be moved from one length of the panel to the other to suit the needs of the gang on the platform below.

Since the sections were hinged, each successive section could be raised as the platform was advanced up the slope and the concrete allowed to drop through the opening this made on the platform below.

The 1-inch topping which consisted of 1 barrel of cement to 500 pounds of sand, was applied to the surface of the concrete in the same manner as the concreting of the slabs.

In lining the side slopes particular attention was paid to obtaining a uniform slump throughout the entire operation. It is obvious that a variation of slump in the successive batches will produce soft spots which would cause the concrete to slough. A 3 inch slump was maintained throughout the concreting of the side slopes. For the bottom slabs a slump which gave the same consistency as for pavements namely, 1½ to 2 inches was used.

LOW SERVICE TANKS AND PIPE CONNECTIONS

The two low service steel tanks, to be described later, are fed from the reservoir by a 24-inch steel pipe dividing into two 20-inch lines, one for each tank. The reservoir may be bypassed by a 30-inch pipe and the tanks fed directly. The 24-inch line from the reservoir parallels the overflow line for a short distance. A crossover is provided between the two lines so that by closing a valve just ahead and opening one on the crossover, the main line to the tanks may be used as a washout.

The outlet consists of a 24-inch elbow with the opening set 5 inches above the reservoir floor. This is surrounded by a circular basket 5 feet in diameter and 5 feet high.

Copper mesh covers the top and removable sections of circular grating comprise the sides. A 12-inch side outlet with valve control provides for cleaning the last few inches of the basin.

As an afterthought a slight modification of the lining on one side was made to provide a roadway 8 feet wide on an 18 percent grade, which is sufficient to admit a truck. This arrangement will be of considerable value in cleaning as well as any repairs or changes which may have to be made in the future.

To handle the low service the two steel tanks, to which we have already made reference, were placed down the hill at approximately 900 feet east of the reservoir. These tanks are 92 feet in diameter, and 33 feet high with an overflow elevation of 320 feet. The tank bottoms rest on a ground area made by dishing out a section of side hill. The foundations consist of a solid concrete mat 97 feet in diameter, 3 feet thick in the center and 4 feet near the edge.

To control the tank level a pair of Golden Anderson valves was placed between the reservoir and the tank.

As the tanks in reality float on the line and might be subject to heavy draw downs, a 3 foot amplitude was desired. Small tanks with floats were placed above the valve. At the bottom of the tanks were located the pilot valves.

When the drawdown reaches elevation 314$\pm$ the floats drop to that elevation and actuate the pilot valves, which in turn open the main valves. The floats then rise to elevation 317$\pm$ at which time the pilot valves are again actuated and the control valves shut. This gives the desired control without the continual hunting of the valves which would have been distinctly undesirable.

SUPERVISION AND COSTS

The design and construction were under the direction of Thomas H. Carver, Assistant City Engineer, and J. H. Quense, Assistant Engineer, both of the City Engineer's Office. The writer was engaged upon the preparation of the plans in the capacity of structural designer.

The contract for the reservoir was let to Elliott, Stroud Bros. and Seabrook. Several of the major contract quantities and bid prices may be of interest.

1. Clearing and grubbing....	30 acres	at $200.00 per acre
2. Stripping..................	60,000 cu. yds. at	0.35 per cu. yd.
3. Earth excavated and rolled..................	245,000 cu. yds. at	0.35 per cu. yd.
4. Earth excavated and wasted..................	15,000 cu. yds. at	0.20 per cu. yd.
5. Slope dressing............	3,200 cu. yds. at	1.60 per cu. yd.
6. Concrete in reservoir lining..................	13,300 cu. yds. at	10.10 per cu. yd.

The writer wishes to acknowledge his indebtedness to Mr. Piper, Principal Assistant City Engineer and to Mr. Carver, Mr. Quense and Mr. Faulkner, all of the City Engineer's Office, for information and helpful suggestions in the preparation of this paper.

The reservoir has been ready for service for four or five months and should adequately serve its purpose for many years to come.

(Presented before the Pacific Northwest Section meeting, May 13, 1932.)

GROUP OPERATION OF WATER UTILITIES

By E. B. Walthall

(*Vice-President, California Water Service Company, San Francisco, Calif.*)

For a number of years past, we have witnessed a persistent tendency throughout the nation, undoubtedly occasioned by economic necessity, to accomplish mass production and mass distribution. This has resulted in groupings, combinations and consolidations of numerous and widespread business interests, together with the creation of centralized management and control, of various kinds, to intelligently administer a business guidance to such. It has also resulted in the replacement of long existing single property security issues with blanket issues covering all of the properties involved in these consolidations. Nearly every line of business has seemingly been affected and not in the least public utilities, including a large number of existing individual water works systems that are now grouped under a single ownership. The California Water Service Company is a typical group operator of water utilities and perhaps the largest in this State. It operates water utilities at twenty-two different points in the State. As the name implies, it is a California corporation. It is directored and managed by California men and has 1697 stockholders, mostly residents of this State. It was organized in December, 1926. It is in every respect under the jurisdiction of the State Railroad Commission. It has acquired, since its organization, the water distributing system at Redding, three systems at Chico, one at Willows, Oroville, Marysville, Petaluma, Stockton, Livermore, Dixon, Bay Point, a system in Contra Costa County, covering both urban and inter-urban territory in the vicinity of Martinez and Concord, South San Francisco, Lomita Park, Hillsborough, San Mateo, San Carlos, Los Altos, Hanford, Visalia, four systems in Bakersfield, Hermosa-Redondo and two in East Los Angeles, totaling 28 separate and distinct water plants.

These twenty-eight properties were acquired from eighteen separate ownerships over a period of four years, the first being acquired in

October, 1926 and the last in July, 1931. Excepting the systems at Redding, Willows, Oroville, Stockton, Livermore and Dixon, one in Bakersfield, two in Chico and one in East Los Angeles, each was acquired by the purchase of all of the outstanding stock of the respective companies owning these plants. The above group of 10 last mentioned involved the purchase of only the physical properties.

The purchasing of these properties has involved a tremendous task, requiring unusual legal and auditing talent, especially those involving stock acquirements. Lengthy and detailed legal investigations had to be made to determine existing rights of numerous kinds. Dependable audits were necessary to ascertain the correctness of varied statements of representation that had been made by the owners in interest concerning the company's past procedures and its recent performances with respect to operating revenues and expenses. Appraisals had to be made for use in proceedings before the State Railroad Commission in connection with the Company's request for the former's permission to issue replacement securities suitable to the newly created conditions existing under consolidation. These several consolidations have resulted in a new capital structure. The physical properties have been subjected to a single trust indenture and the security issues formerly existing on each plant were entirely eliminated concurrently with the purchase of each of the plants and its consolidation with the other interests of the California Water Service Company.

Several of the acquired properties have been physically connected where close proximity of location permitted. This has occurred in the case of three properties at Chico, four in Bakersfield, two in East Los Angeles and two in Contra Costa County. Where physical connection has been made, the combined properties have become a unit for the purpose of operating and investment accounting and reporting operating results to the State Railroad Commission.

Consolidating of items affecting revenues and expenses takes place in the General Office only after the revenues of each plant have been separately recorded and joint operating expenses properly allocated, thus enbaling the Management to determine quickly and accurately each plant's contribution to the success of the enterprise as a whole and to bring the spotlight of comparison on the results obtained by each of the Local Managers.

For the purpose of placing operating responsibility, the State is divided into two divisions, namely the Northern Division and the

Southern Division. The responsibility for operating results in these divisions is placed on two Division Managers, stationed at the General Office. The Redding, Chico, Willows, Oroville, Petaluma, Dixon, Stockton, Livermore and Contra Costa County plants being in the Northern Division and the San Mateo Peninsula, Visalia, Hanford, Bakersfield, East Los Angeles, Redondo and Hermosa Plants being in the Southern Division. Each plant has a Local Manager upon whom the responsibility for local operating results is placed. The six plants in the San Mateo Peninsula group are directly supervised by a District Manager, who is also the Local Manager at San Mateo. The East Los Angeles, Hermosa and Redondo plants are directly supervised by a District Manager, who is also the Local Manager at East Los Angeles. The Redding, Chico and Willows plants are directly supervised by a District Manager who is Local Manager at Chico.

The General Office of the Company is located in San Francisco to which each of the Plant Managers forwards miscellaneous monthly reports pertaining to the results of the past month's operations. The work in the General Office is divided into several departments, namely, Engineering, Financial-Accounting, Property-Insurance, Tax, General Stores, Purchasing and Stock Selling Departments.

ENGINEERING DEPARTMENT

The Engineering Department designs and installs such improvements as are not what may be termed of major importance. Extraordinary maintenance and the designing and installing of improvements of truly major importance are handled by outside engineering talent, especially employed for the occasion.

FINANCIAL-ACCOUNTING DEPARTMENT

The Financial-Accounting Department is responsible for the proper and adequate recording of all local office reports on the results of operations, the accounting for capital expendtures to which unusual attention is given that it may be exceptionally accurate; the preparation of all statistical data; the supervision of the collection of all revenues; the disbursement of all company funds; the compilation of many and varied daily, monthly and annual financial and operating statements, and in general keep the Company's executives, local managers, stockholders and bankers regularly and comprehensively informed of operating results and the status of the Company's affairs.

Three travelling auditors from this department are continually visiting local offices. In addition, an inspector is continually in the field for the purpose of inspecting consumers' premises for theft of service, inventorying uncharged for fixtures and unauthorized connections, as well as to report any condition he may observe that would be of interest to the Management.

PROPERTY-INSURANCE DEPARTMENT

The Property-Insurance Department has the responsibility for maintaining a convenient and permanent file of all of the Company's corporate records of property owned, and of its numerous important contractural obligations, properly tabulated and registered for identification and description. It has the responsibility for the full protection against fire of all insurable property by means of adequate insurance coverage and also for properly insuring the Company against its several liabilities for the safety of persons and property. Centralization of responsibility for adequate insurance coverage of various kinds, together with a consolidation in ownership of a large number of diversified and scattered holdings has enabled the Company to offer attractive risks on a competitive basis to those concerns that are in the insurance business. This has resulted in the Company obtaining greatly reduced insurance rates, considerably below those formerly prevailing when its plants were individually owned and operated by its predecessors in interest. At this point it might be of interest to mention that the Company offers each of its employees an extremly attractive Group Life Insurance Plan.

TAX DEPARTMENT

The Tax Department is in charge of a trained tax expert, and as its name implies, has the responsibility for making tax returns of every kind and nature. It deals with thirty-four City and County assessors in this State. Owing to the consolidation of so many different water companies with a newly created one, followed by the dissolution of those same companies, many intricate income tax problems have naturally arisen that have required the services of an expert to formulate correctly the numerous income tax returns to the Federal Government.

STORES DEPARTMENT

The Company regards the matter of accurate accounting for all materials and supplies purchased and used as of the greatest impor-

tance. It maintains a perpetual inventory in its Stores Department in the General Office through the medium of a machine operated card system. Every item of materal withdrawn from, and every item returned to stores is systematically recorded and the proper accounting and distribution made shortly after the same occurs at the storerooms of the various plants. A travelling auditor from the Stores Department is continually visiting the local plants checking inventories and reporting differences to the Chief of that Department. Unaccounted for materials are thus reduced to a minimum if not entirely eliminated.

PURCHASING DEPARTMENT

Most of the purchasing is done by the Purchasing Department at the General Office of the Company in San Francisco. Small items aggregating not more than \$30.00 in a single purchase, or emergency items involving a greater amount, are purchased locally and invoices for same are paid locally by means of a revolving petty cash fund. Such standard articles of use as would come within the \$30.00 limit at any one plant, but that would amount to a much larger sum when considered in the aggregate for all plants, are requisitioned for by each plant on the Purchasing Department. The latter consolidates these requisitions and seeks competitive bids for the furnishing of same and where possible from concerns in the communities served by the Company. This results in annual savings of considerable magnitude being effected. Due to the Company being an operating unit of a national concern and thereby enjoying the low prices resulting from nationally made contracts for numerous standard major items of material, supplies and equipment further savings of a considerable magnitude are enjoyed.

STOCK SELLING DEPARTMENT

This Company is not unlike many other utilities operating a group of properties in that it strives to place its preferred stock issues with the public in general and its own customers in particular, believing that the customer ownership plan of conducting its enterprise is mutually beneficial to both the company and its investing customers. Its customers, through their need for service and the Company through the rendition of that service by an efficient and trained personnel, each contributes their share to the success of the utility enterprise. By the purchase of the Company's preferred stock the

customer is enabled to enjoy a fair return from a safe investment and the Company is enabled to conveniently and economically raise a portion of the necessary funds required to improve and extend its properties and enlarge its enterprise. The responsibility for the conduct of this department rests with a directing employee collaborating with all of the other employees who recieve a fair commission for their efforts.

GENERAL

The Company has 58,450 consumers; 12,750 receive their service on a flat rate and 45,700 receive theirs through meters. It has 934 miles of mains installed as well as 3370 fire hydrants. Its organization consists of 350 employees.

The Company centralizes its control of expenditures for improvements and maintenance in its executives through a comprehensive budget system, annually prepared. Budget infomation is systematically ascertained and carefully compiled throughout the year and then is formulated into the budget at the end of the calendar year. Executive approval is obtained early in the following year. Budget approval is then followed from time to time throughout the year by both blanket and specific requests to make the expenditures thereunder. These requests are itemized in detail as to material, hauling and labor requirements and each makes reference to a previously approved budget item. They orginate in the Local Offices, except as to extraordinary maintenance and major improvements which originate in the Company's Engineering Department in collaboration with outside engineering services that may be specifically employed for the occasion. Local Managers participate to the fullest extent in the preparation of the annual budget and are encouraged to bring to the attention of the executives of the Company any and all items that they deem to be desirable in order to maintain a high standard of service and satisfactory public relations. They are permitted to make single expenditures of $50.00 or less without specific approval of the Executives either for improvement or maintenance.

LOCAL PLANTS

The Local Manager is held responsible for the results at his particular plant. His organization is divided into two operating groups at the smaller plants, and four at the larger plants, except for the one man plants. One of the groups at the smaller plants is held responsi-

ble for production, distribution and construction, the other being responsible for the office work and the accounting. The former is headed by a competent foreman, the latter by a Chief Clerk. At the larger plants there is a production group, a distribution group and a construction group, each headed by a competent foreman reporting directly to the Local Manager and the fourth group headed by a Chief Clerk, who reports likewise and is responsible for the accounting and office work. The Local Manager is the representative of the Company in all of its affairs at his plant and its responsibilities are centralized in him. All executive orders, instructions and correspondence from the General Office are directed to him. He has entire charge of the personnel and coördinates and directs its activities. He is selected for his ability to do this effectively as well as to maintain satisfactory public relations and to handle wisely and discreetly the many and varied problems arising daily at his plant. Local Managers are rewarded for progressively improved operating results and promotion from the ranks is strictly adhered to. Thus initiative, enthusiasm and personal endeavor are stimulated without which no company can hope to accomplish the best results.

Standard practices are maintained in so far as is possible throughout the system and standard forms carefully designed to secure whatever information the General Office may need are in use at each of the plants. A request for the approval of a change in a standard practice and a requisition for a replenishing supply of an existing form, as well the request for the adoption of a new form is always carefully considered before action is taken so that standard forms and practices may be either continued at all plants or any alteration in such be made effective throughout the system.

Local plant payrolls are handled entirely by the Local Offices. The employees are paid by local company checks drawn on a local bank and on a fund deposited there by the General Office, known as the Payroll Fund. The General Office deposit is made following advice to it by the local office of the total amount due. Advances to employees between the semi-monthly pay dates and amounts due them on account of termination of employment are paid by local office time checks drawn on the General Office which are readily cashed by local banks. The company keeps a deposit account with practically every bank that is established in the various communities in which it has a plant, some seventy banks in number. Freight invoices are paid by freight drafts drawn on the General Office and are also readily cashed by the local banks.

The system of local office accounting requires the accumulation of all disbursements against authorizations for capital expenditure, as well as of local disbursements against operations, thus promptly bringing to the attention of the local manager any disbursements in excess of authorized amounts, which are strictly forbidden and thus enabling him to formulate an early report on local operating costs for the current month, including comparative figures with the corresponding month in the previous year and the reason for any important increases or decreases. Every report emanating from the Local Office, as well as those from the General Office, are scheduled for completion upon a certain day of the month, thereby enabling responsible executives to review results early in the current month and on about the same date in each month.

All consumers bills with the exception of those at one plant, which is due to the peculiarity of the local rate, are made out on postal cards by means of addressographs and suitable billing machines and are mailed to the consumers immediately afterward from the respective plants, using postage purchased from the local postoffice. The billing for the entire Northern Division is done at Stockton and for the Southern Division at East Los Angeles to which points the several meter reading and flat rate account books are forwarded regularly from each of the plants throughout the month. The forwarding of these books is scheduled in such a manner as to utilize evenly the full capacity of the billing machines and their operators, thereby preventing abnormal peaks and excessive congestion in this phase of the Company's operations.

The East Los Angeles office makes out 37,450 bills per month, and the Stockton office 27,600.

ACCOMPLISHMENTS

In the inauguration of a group operation of water utilities with its centralization of management and control, many important problems involving organization and operation are at once encountered. Unquestionably the most important of these is the procurement of an able and experienced management that is possessed with a strong leadership, together with an organization that will work cooperatively to support that management, each employee of which, occupying a position of trust and responsibility, has been selected with due regard for the employee's ability, training and experience in handling water works operations.

Upon the management will rest the responsibility for formulating the company's policies and establishing its operating procedures; for the selection particularly of the key men of the organization; for the delegation to the latter of their respective responsibilities; for expeditiously and comprehensively acquainting them with established policies, procedures and responsibilities; for carefully and systematically supervising their activities, and finally for imbuing the personnel, through the key men of the organization, with initiative and the spirit of economy and efficiency.

The organizers of the California Water Service Company. In entering the field of group operation were mindful of all of these problems and as they encountered them, endeavored to solve them successfully.

If the achievements of the Company with group operation of the plants composing its system as compared with the achievements of single unit operation of the same plants under individual ownership, are any criterion, then it may be said that both the organizers and the management have met with a measurable degree of success.

Operating ratios have been progressively bettered without materially altering formerly established rates; standards of service and construction have been greatly improved upon; demands for extensions occasioned by community development have been more readily complied with and the Company's security issues have been made unusually attractive to critical and exacting investors.

This has been accomplished in part by carefully analyzing the past operations of each of the plants now constituting the Company's group immediately upon their acquisition and then altering operating procedures, rearranging the personnel, removing general accounting to the General Office and reducing overhead expenses. In addition to this and to those savings effected through the Insurance and Purchasing Departments, already mentioned, other major savings have been effected by the installation of automatic pumping equipment, thereby reducing pumping attendance and use of electric power; by the replacement of leaky and worn out mains with cast iron pipe, thereby eliminating expensive maintenance costs; by the centralization of consumers' billing and use of billing machines at two points in the State, thereby reducing clerical help and auditing expense; by the inspection and repair of meters, thereby increasing revenues; by regularly and systematically inspecting consumers' premises, especially at flat rate plants for water deliveries unrecorded

on the books, and properly applying existing rates, thereby further increasing revenues; by mailing consumers' bills and exacting payment of same on a definite date at the Company's office, thereby largely eliminating personal collections and reducing collection costs; by replacing inefficient pumping equipment with efficient equipment suitably adapted to the characteristics of the water supply, usually wells, thereby further reducing power costs; by carefully analyzing the electric rates, rules and regulations of the several electric utilities serving power to the Company, and adopting rate schedules and service regulations better suited to existing pumping conditions, thereby further substantially reducing electric power costs which now amount to approximately $250,000 per year; and by regularly and comprehensively keeping Local Managers and Executives advised of operating results that various comparisons may be made, that any weaknesses may be disclosed and that corrective measures may be promptly taken.

In many and various ways have small economies been effected at each plant of the group. In the aggregate of all plants, these savings have amounted to a substantial and an appreciable sum. There has been a fertile field for effecting these small economies in closely observing petty cash disbursements for the purchase of needless articles or for standard articles of use that should be combined with other plants' needs for the same article and purchased in the aggregate through the purchasing agent; in the use of equally as good but less expensive lubricants and in the bulk delivery of same together with gasoline; in the use of telegrams instead of the telephone; in the needless illumination of pumping stations, store yards and storerooms; in hauling and drayage, that can be done by the Company's equipment; and in not junking automobile tires, small tools and appliances until they have reached their limit of usefulness.

(*Presented before the California Section meeting, October 29, 1931.*)

MAINTENANCE OF VALVES AND HYDRANTS

By W. H. Durbin

(*Superintendent, Terre Haute Water Works Corporation, Terre Haute, Ind.*)

Valves and hydrants in the distribution system are unlike pumps and other pieces of machinery in that they are very seldom used and for this reason, their conditions must be determined by inspections made at more or less definite intervals of time.

The first requisite at any water works plant is an up-to-date map showing the location and sizes of all mains, valves and hydrants.

VALUES

All valves in the distribution system should open one way and if this is not the case, new stems and nuts should be installed so as to bring about a uniformity in their operation. To allow valves to remain where part open by turning to the right and others to the left usually results in unsatisfactory service, twisted stems and a higher maintenance cost. The necessity of uniformity can not be too strongly emphasized.

Every valve should be dimensioned, using some permanent point for reference. Each foreman should be furnished with a convenient record that is always kept in his possession, showing the location, direction the valve looks, size, turns to open, whether open right or left if uniformity does not exist, make, etc. At Terre Haute, every valve is numbered and these are shown upon an index map, while the dimensioned locations are shown upon sheets provided for this purpose, the point of reference usually being the property line.

It is our practice to try to inspect every valve once each year. A permanent card is made out for this purpose and the date of inspection, condition of valve and valve box, party making the inspection and other information of a similar nature are shown upon it. It is not considered advisable to make a practice of completely shutting off a given section of the City for the purpose of determining the condition of the valves unless there are exceptional reasons for doing so.

The usual inspectional consists in placing the valve key upon the nut and making several turns in order to determine if it operates freely, also to make certain that the valve is fully open. If the valve does not work freely and the party making the inspection does not think it advisable to try and force it, this fact is noted on the card so the valve can be given proper attention. The operation of a valve is often made more difficult by the packing drying out. Where this is the case, considerable relief can be obtained by removing the stuffing box gland, loosening up the packing, and at the same time, lubricating it. All valve boxes are adjusted to the grade of the street if these are found covered.

At one time, it was the practice at Terre Haute to install brick wells or vaults on every valve located in a paved street irrespective of its size. Our experience has demonstrated that the cost of maintaining the valve wells and especially the iron cover is far in excess of any expense incurred in the valves themselves. It is very seldom necessary to repack a valve and where this is needed, it is usually more satisfactory to dig up the street rather than maintain the well. Should the stem become broken or bent, even with the ordinary well, it is often impossible to make the needed repairs without removing the cover and possibly some of the brick work. Under heavy automobile traffic, it is almost necessary to use a malleable lid to prevent breakage and this still further adds to the cost. On a geared valve, we believe that the vault is advisable, but on a straight operating valve of 16-inch or less in size, it is, in our opinion, not necessary.

HYDRANTS

The fire hydrants serve a very important purpose in the distribution system and it is very necessary that they should always be in first class working order. At Terre Haute, two general inspections are made each year at which time the hydrant is opened and closed, packed if necessary, revolving nut lubricated, nozzles properly leaded, drains opened, etc. In addition to the two general inspections noted, visits are made several times during the winter months, the frequency depending upon the location and weather conditions. Where the ground water plane is above the drain in the hydrant, the drain opening is closed and the hydrant pumped. Each hydrant is inspected after its use by the Fire Department and especially is this important during the winter months.

A permanent record is kept on cards at Terre Haute, which shows

the hydrant number, size, make, number and size of nozzles, street main to which hydrant branch is attached, whether valve is on hydrant branch or not, date ordered by the City, etc.

The exposed condition of the hydrant makes it very susceptible to breakage from automobiles and trucks. For this reason, they should be placed well back from the curb line and at a point where they will not be struck in turning corners at street intersections.

Several different lubricants have been tried at Terre Haute upon the revolving nut and the most satisfactory results have been obtained by using the heavier grade of transmission oil. Plumbago mixed with the lighter grade of oil did not prove satisfactory due to the oil either evaporating or running off in the warm summer months and thus leaving the dry graphite, which in the winter offered practically no lubrication. Glycerine was used for a time, but this furnished lubrication for only four or five months. Glycerine does not have sufficient body to furnish proper lubrication under the severe weather conditions that a hydrant is placed. The heavy grade transmission oil will last, under ordinary circumstances, about two years.

The most satisfactory packing that has come to our attention consists of a square spiral packing with a hole in the center. The hole in the center gives a greater flexibility and in this way, the packing is capable of taking up any wear or roughness on the stem. The particular grade used at Terre Haute has been furnished by the Crandall Packing Company in $\frac{1}{2}$ and $\frac{3}{8}$-inch sizes.

All hydrants should open one way, and the nozzles should be equipped with the National Standard Thread. Should a different thread be in use, this can be chased by securing an outfit from the National Board of Fire Underwriters, which they are willing to loan.

We do not favor the use of chains on the hydrant caps, since these usually rust and are very difficult to remove by the firemen.

Contractors are not permitted to use hydrants at Terre Haute for construction purposes and where water is desired, a tap is made, usually in the hydrant branch, and a meter temporarily installed.

Where sewers are to be flushed or inlets cleaned, the Street Department notifies our office and a controlling valve is placed upon the hydrant. As soon as the work has been completed, the hydrant is shut off by our men and the valve removed. The street foremen are not permitted to open and close the hydrants.

The cost of making repairs to hydrants broken by automobiles is charged against the party who caused the damage, providing the per-

son can be located. Very often a collision has been the cause of the broken hydrant and in this event, it is not possible to place the blame on any one person, unless the matter is taken to the Courts. We have never attempted to force collections by this method. The number of broken hydrants from automobiles is continually increasing and this has added an additional expense to our maintenance.

The Terre Haute Water Works Corporation owns an acetylene torch that is used in repairing broken hydrants as well as in doing other work around the plant. This has been found to be of great value and its use has saved the Company a large amount on repair bills. If the ground has been filled around the hydrant so as to make it too low, a piece is welded into the barrel so as to bring this to the proper elevation. The uses of the welding torch are so numerous that every water works plant of any size should have such an outfit.

Repair parts of every make and style of hydrant should be kept in stock. In the event a hydrant is broken, it is our practice to remove the old barrel and install another in its place. Repairs are then made at a later date to the broken part, providing, of course, the damage is not too severe. In this way, the City is without protection for only a minimum of time. Every hydrant should be installed with an independent valve on the hydrant branch, so repairs can be made without shutting off the mains in the street.

(Presented before the Indiana Section meeting, March 10, 1932.)

AUTOMATIC AND REMOTE CONTROL FOR ELECTRIC PUMPING STATIONS

By R. C. Allen
General Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

There have been radical changes in the methods of city water pumping since the day of the mammoth slow speed vertical steam units requiring a large outlay of capital for the pumping and steam plants and a corps of experts in constant attendance. Unfortunately, the "corps" was not always made up of experts and the city fathers did not always realize, until too late, that upkeep and man efficiency were vital to the life of any plant.

The modern plant has, however, eliminated much of this outlay and uncertainty by the use of the centrifugal pump, motor drive and automatic control. The stations are generally smaller and it is possible to locate them, using central station power, at the most advantageous point in the system, irrespective of the character of the surrounding residences. (Fig. 1.)

The simplicity of the electric drive and ease with which automatic and protective features can be incorporated open up a field of possibilities for further reduction in the cost of pumping water by reducing the cost of attendance or supervision required in the present day plant. The satisfactory results obtained from modern control equipment in private water and pipe line pumping indicates the possibilities of incorporating similar control for municipal pumping plants.

STARTERS

Motor starters can be divided into full voltage starters and reduced voltage starters. Most squirrel cage and synchronous motors are designed for full voltage starting, i.e., starting by throwing the motor directly on the line through the main or running switch. With this method of starting, the motor takes the locked current from the line at the instant of starting. The acceleration is very rapid but the energy required is essentially the same as for reduced voltage starting.

The power company rulings regarding allowable motor starting current generally determine which type of starter will be necessary. Motors are available, having low starting current characteristics to permit of the simple full voltage starter, but occasionally, and particularly for large motors, the power company rules necessitate using reduced voltage starting.

Reduced voltage starters are of the auto transformer, reactor, or resistance type. The *auto transformer method* gives the lowest start-

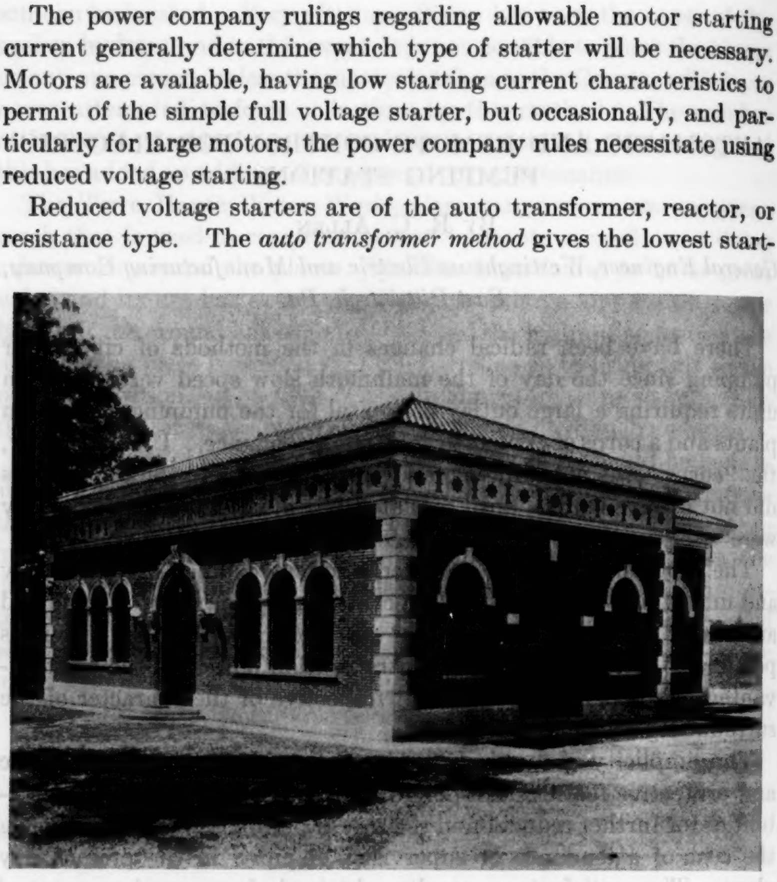

FIG. 1. GUILFORD PUMPING STATION, LOCATED IN THE RESIDENTIAL SECTION OF BALTIMORE

ing current for the torque delivered, but requires, in general, open circuit transition, i.e., the line must be disconnected when going from the reduced voltage auto tap to the line voltage. This is sometimes objectionable for large motors, as it gives the power line a second current surge.

Reactor starters use the closed circuit transition and this type is generally specified for large motors, particularly for pump drives as the starting torque required by a centrifugal pump is sufficiently low, so that one step of reactance will reduce the starting current to the

required value and yet give ample torque for accelerating to a high speed before applying full voltage by shorting out the reactor.

Resistance starters are used in place of reactor starters for the smaller motors, but have essentially the same characteristics. These are sometimes required on network systems because of starting current limitations.

Wound rotor motors require resistance type starters and are used occasionally to meet starting current limitations, but more frequently to secure adjustable speeds required by the driven unit.

Any of the above types are designed to give the motor full protection by incorporating one or more of the following features as required:

- Overload protection
  - Thermal type
  - Dash pot type
  - Induction relay
- Low voltage protection
  - For protection to operator
- Low voltage release
  - For full automatic controls
- Loss of one phase
  - Protected by operation of over load trip
- Loss of field (for synchronous motors)
  - Protected by operation of overload trip

Other protective features can be incorporated on special controls, but they are generally more for line protection than for motor protection, and are a part of the circuit breaker control. Incidentally, short circuit protection requires that full current or power back of the switch be interrupted instantly and without injury to the apparatus. This necessitates a circuit breaker ahead of or a part of the motor control.

TYPES OF CONTROL

The types of controls available for these starters can be classed as follows:

- Hand or manual
- Semi-magnetic
- Push button or full magnetic
- Full automatic
- Remote direct wire
- Supervisory control

In the *manual control*, the operator performs all the control functions by hand. This necessitates an attendant somewhat conversant with electricity and electric control. This type of control is confined chiefly to reduced voltage auto transformer type of starters for squirrel cage motors and to full voltage starters, using a circuit breaker, for the large motors.

Some starters, particularly for synchronous motors, are *semi-magnetic*, i.e., part of the starting cycle is performed automatically in order to simplify the operation for the attendant.

Most pumping stations, and especially the larger plants, have *full magnetic type* control requiring only the operation of a button or master control switch for starting or stopping the pumping unit. The complete starting cycle is carried through in proper sequence, after being initiated by the attendant. Even the operation of auxiliary equipment, such as main valves, priming pumps, etc. can be included in this starting cycle and interlocked so as to secure the desired sequence. This greatly simplifies the starting operation and removes much of the responsibility for correct operation of the equipment from the attendant. With motor operated valves a single operator can easily handle a complete station.

With *full automatic control* no attendant is, theoretically, required as all of the functions of the station are performed automatically by means of magnetic control actuated from pressure gauge relays or similar master control. If a fault develops in any unit it is locked out, an alarm given, and another unit started up automatically. This type of control is used extensively for small stations, especially where only a day operator is otherwise required, but it is also gaining favor for the large plants as it reduces the number and responsibilities of the necessary attendants.

Baltimore Guilford Station

The 50 M.G.D. Guilford Station in Baltimore, is probably the largest completely automatic water pumping station. The automatic control system incorporates the protective devices of over current trip, reversed phase due to reversed wires, serious unbalance of current or voltage in the system, as well as bearing temperature and pressure cutouts. In the event that one unit is taken off the line, due to the development of a fault, the unit is locked out until attention is received, and the load transferred to the next unit automatically. (Fig. 2.)

The governing of this plant is unique. A pump in service continues to run until the reservoir is within 3 inches of being full. When the level is reached a valve controlling the flow of water into the reservoir is closed automatically resulting in a few pounds increase in the pressure of the entire system. This rise in pressure is limited by a small overflow standpipe at the reservoir, but the increase is pressure is sufficient to cause a pressure relay at the pumping

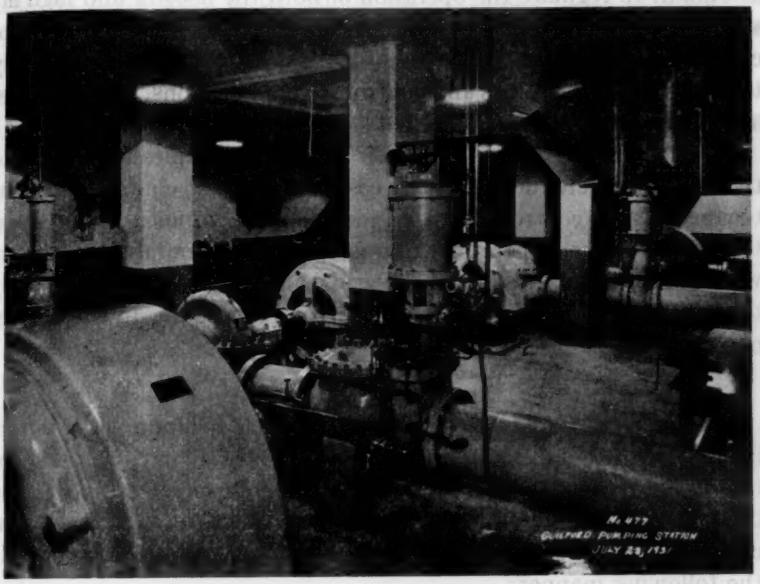

FIG. 2. GUILFORD PUMPING STATION WITH SYNCHRONOUS MOTOR DRIVEN PUMPS FULLY CONTROLLED AND PROTECTED BY FULL AUTOMATIC CONTROL LOCATED ON THE MAIN FLOOR

station to make a contact that initiates the shut down operation of the control equipment.

When the shut down indication is given, a timing clock begins to operate and, after the end of the pre-determined time interval for which the clock has been set depending upon the season of the year, a contact is made which again places the pumping unit in service. The clock, at the same time, is shunted out and performs no further timing function until the unit is again stopped.

The *remote direct wire control* is of the type where the plant is operated or controlled by master switches from another plant, but

in the same manner as for magnetic control except for the distance between the control desk and the apparatus. This, it is evident, will or may require a large number of control wires between the two plants, especially if signals are included to give the operator a complete indication of the plant operation.

The particular application for this type of control is for the booster station in the same locality as the high lift station as this enables one attendant to regulate the operation of both the booster and high lift stations from a common control desk. On this desk would be located the master control buttons, meters, signals, etc. for not only the control of the motors and control for both stations, but for valves and auxiliary equipment if desired.

The application for this control is limited, economically at least, to those plants where the chargeable cost, i.e., the fixed charge and maintenance of the control wires and automatic equipment, figures less than the replaced operator or supervisor. The number of control wires can be reduced by making the station full automatic when only the master and signal wires will be required to indicate the correct operation of the plant.

Erie Station

This type of control has already been applied to a number of pumping stations a notable example of which is the new water works station in Erie (Fig. 3). Here the master control is in a control desk on the balcony of the high lift station from which a single operator has complete control of the two stations, as well as the filtration plant, in the following manner:

High lift station:

- Operation of two main breakers with indicating lights.
- Control of three synchronous motor pumping units with indicating lights and meters.
- Control of synchronous motor field rheostats for power factor correction with meters.
- Water pressure gauge indication.
- Meters for line voltage and current.

Low lift station:

- Starting of vacuum pumps with indicating lights which in turn automatically start the low head pump selected, with signal indication.
- Auxiliary control for mixing tanks and stopping of dry feed mechanism.

Control of wash pump.
Auxiliary control of balancing pump.
Current meters for feeder to low service.

Of course, the low head station equipment is provided with protective devices, such as bearing thermostat cutouts, pressure failure cutouts, overload cutouts, etc., so that a fault of any description not only shuts down the unit but signals the operator who can immediately investigate to determine the cause and make necessary adjustments or otherwise handle the trouble. The desk can be closed with a glass top cover and locked when not being operated.

Fig. 3. Erie Water Works. Low Head Pump Room. Motors Controlled from Control Desk in High Head Station

In all cases push button stations, located near the apparatus, permit of local operation of each unit independently of the control desk, thus making a very flexible operating equipment.

A relatively large number of wires for control buttons and lights are required between control desk and the station. For far distant stations this expense becomes prohibitive. Supervisory control permits the performance of all of these functions and many others over only two or four wires.

Supervisory control was originally designed to meet the demand for remote control of railway, mine, and power substations, where the

type of operation did not really require the presence of an attendant and where the chargeable expense for wires and pole installation and the automatic equipment was less than the salary of the replaced operator. This type of control also replaces the remote direct wire control where the drop on the control becomes prohibitive. It has, also, been used very satisfactorily in a number of pumping stations.

Examples of supervisory control

The pumping plant at the Chase Metal Works, Cleveland, was originally laid out for direct wire control but, because of probable line drop, supervisory control was finally installed. This equipment initiates the starting and stopping of the three pumping units and gives complete visual indication of the plant conditions over only two wires.

Supervisory control was applied to the control for water pumping by the Atchinson, Topeka and Sante Fe Railway Company at Indian Garden Springs, Grand Canyon, Arizona. Here two pumping units, each consisting of two 17 stage centrifugal pumps in series, lift the water some 3000 feet through approximately 12,000 feet of pipe to the tourist hotel on the rim of the canyon.

The plant is unattended and all starting and stopping of the pumping units, as well as operation of all valves, are handled over the two wire supervisory control. This has proven exceptionally satisfactory because it not only saves the expense of an operator, but the plant is very difficult of access from the hotel. Electric power for operating the plant is obtained from the power plant adjacent to the hotel.

Previously to building the pumping station all the water used at hotel, power plant, etc. had to be hauled in tank cars from a distance of approximately 75 miles.

The War Department at Washington has a simplified supervisory control called Televox for obtaining readings of the water levels of any of the three dams of the Dalecarlia Pumping Stations. From any of their telephone stations the telephone at the dam can be dialed when the Televox will lift the receiver and indicate, by the number of buzzes, the height of the water. The buzzer is, of course, controlled by a water level float through a number relay.

Pipe line pumping stations

Recent extensive expansion in the pipe line pumping industry has resulted in a great deal of interest in electrifying such stations.

Such pipe lines are now used to transport oil, gasoline, gases, etc., over long distance. One of the first electrified automatic pumping stations was recently placed in service by the Texas Empire Pipe Line Company, at Sands Springs, Oklahoma. This station is controlled from a dispatching office located in Tulsa, Oklahoma, some 15 miles away.

The pumping station consists of three motor driven centrifugal oil pumps, each driven by an 800 h.p. motor. The supervisory control is arranged to start and stop the pump motors and also control the exciters, as well as a motor operated valve. The pump motors are locally controlled by suitable automatic switching equipment after they receive the start or stop impulse from the supervisory control. The status of a number of devices associated with the automatic switching is given by continuous lamp indications over the supervisory equipment to the dispatcher. These indications include lock out for each pump, station lock out, low voltage, phase unbalance, phase failure, position of the line breaker, and the position of three manually operated valves.

A unique device was developed in conjunction with the supervisory control for this application. It was necessary to provide the dispatcher with indications of suction and discharge pressure. To do this and not use any extra line wires required the use of contact making pressure gauges, but a suitable gauge was not available, making necessary the design of a new type of pressure gauge. At the dispatching office, each gauge is represented by ten indicating lamps and the gauge contacts are so interlocked that one of these ten lamps is always lighted, giving an indication of pressure. Thus the dispatcher is kept fully informed of conditions and can operate the remote pumping station in the most efficient manner.

To be acceptable for control of remote pumping plants, supervisory control should enable the dispatcher to perform any desired operation in the distant plant by the manipulation of simple master switches and have a visual indication of the condition of the plant at all times, just the same as if the equipment were in the same room, but do it over only two wires. This might not seem possible until you realize that any subscriber on your telephone exchange can be reached over only two wires by simply dialing the desired telephone number. In fact, supervisory control employs telephone relays and similar codes or impulses for selecting the units to be operated.

There are various systems available in securing supervisory control but the three in general use are synchronous visual system;

coded impulse system, called Visicode; direct selection system, called Polaricode.

To obtain an idea of the different principles involved in the three general systems now available, imagine a row of small control keys with indicating lamps in a dispatcher's office and a corresponding row of circuit breakers in a distant station. Two or four wires are used between the units in the systems, depending upon the number of operations to be performed. When the number of operations is small, two wires are used while four wires prove more economical in the larger installations. For pumping plant operation, two wires would undoubtedly handle all the operations required.

In the *synchronous selection system* the line wires are switched synchronously at each end from point to point. This means that wires used for control and indication are first connected to the first control key and the first circuit breaker. Both ends of the wires are then simultaneously disconnected from the first control key and breaker and connected to the next key and breaker. This action is repeated until the desired breaker is reached. This breaker is then opened or closed by direct control and corresponding indication received.

With the Visicode or *coded impulse system* the selection is made by a definite number of electrical impulses counting up to the desired circuit breaker and the selected breaker sending a corresponding selection or check back to the operator key in the dispatcher's office. Again the breaker is opened and closed as in a direct control system and the lamp signals received.

The Polaricode or *direct selection system* is a new departure from previous systems as selection is made by single, direct acting impulses which are sent from the selection key straight to its corresponding breaker in the substation and signal checking impulses returned. After selection the breaker may be opened or closed at will and the corresponding lamp indications received.

Any of these are satisfactory for pumping station control, but the visicode and the Polaricode systems are the more desirable as only two wires are required for the results desired. Although any of these systems are, electrically, simpler than may sound from the above description, it is difficult to convey in words the actual methods of operation. Let us consider, however, the Visicode system.

Visicode system

Visicode is an electric system using relays similar to those employed for years in automatic telephone systems. For each apparatus re-

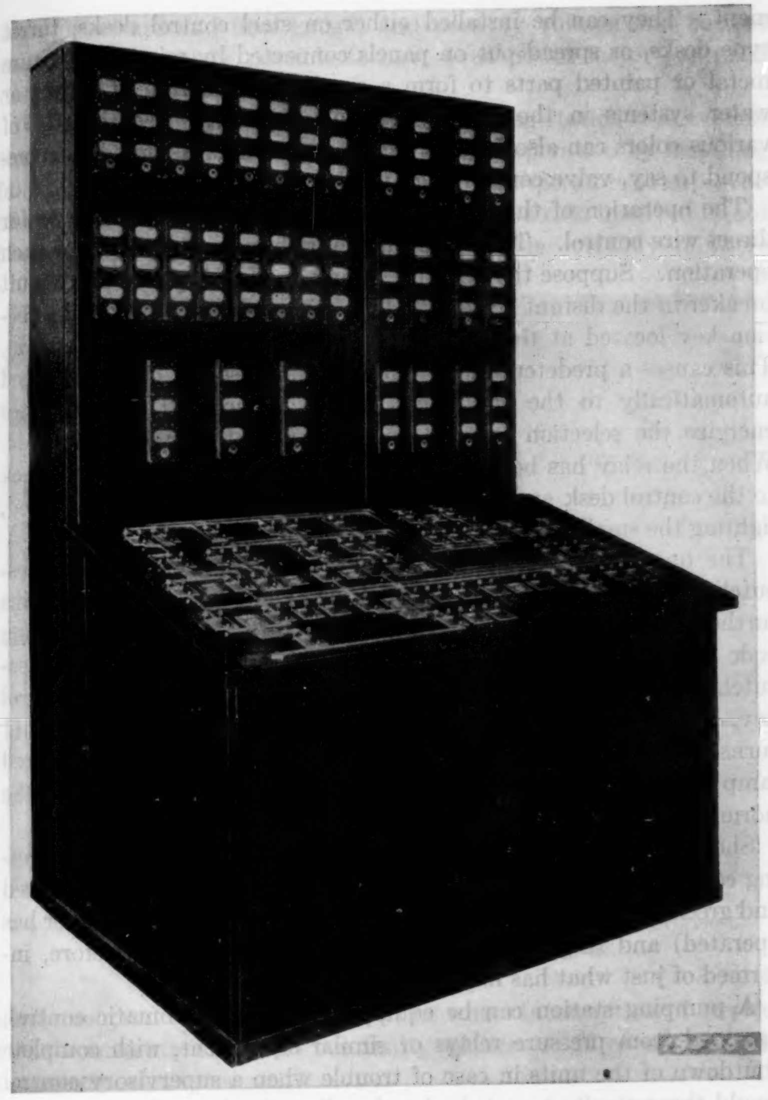

FIG. 4. DESK TYPE OF MINIATURE SWITCHBOARD

This board gives operator complete control, with visual indication of the entire plant.

motely controlled and supervised, there is provided an individual control key with indicating lamp on a Moldarta escutcheon. The escutcheons are simple panels or shields on which are mounted the control keys and indicating lamps for one piece of controlled equip-

ment. They can be installed either on steel control desks, turret type desks, or spread out on panels connected by mimic, miniature metal or painted parts to form a single line diagram of power or water systems in the remote station. (Fig. 4.) Escutcheons of various colors can also be used and certain colors assigned to correspond to say, valve control, high tension control, etc.

The operation of this system is as simple for the operator as for direct wire control. There is a button with indicating light for each operation. Suppose the operator desires to close a particular circuit breaker in the distant station. He first presses the individual selection key located at the bottom of the escutcheon for that button. This causes a predetermined number of impulses to be transmitted automatically to the equipment in the station. These impulses energize the selection relay corresponding to this particular code. When the relay has been energized the same code is repeated back to the control desk and causes a corresponding relay to be energized, lighting the small selection lamp at the top of the escutcheon.

The operator is thus informed that the circuit between the escutcheon and the curcuit breaker has been established and awaits his further direction. The operator can then initiate the breaker closing code by moving the twist-type control key, in the center of the escutcheon, to the "closed" position and depressing the master control key. The operation of the circuit breaker initiates a return code that turns off the green light indicating "breaker open" and lights the red lamp to indicated "breaker closed" and returns the equipment to the normal position of rest.

Should a breaker change its position automatically the corresponding code is sent automatically to the control board to change the red and green lamps, light a disagreement lamp (showing the breaker has operated) and ring an alarm bell. The operator is, therefore, informed of just what has happened.

A pumping station can be equipped with full automatic control, operated from pressure relays or similar equipment, with complete shutdown of the units in case of trouble when a supervisory control would theoretically be required to handle only the major operations with direct indication in case a fault develops.

It is desirable, however, to have complete indication of the position of all circuit breakers, controllers, and valves, and auxiliary control of all the major units with at least means of checking the operation of each unit and the plant as a whole. This would require remote meter-

ing of pressure and flow gauges and possibly voltage and current meters. It would be possible to have even power factor control if desired.

With the modern electrically driven pumping station it is evident that much can be done to reduce the cost of operation by installing full automatic equipment and have one or two operators to supervise all plants from a common control station. The risk involved in not having attendants present in every station is certainly nowhere

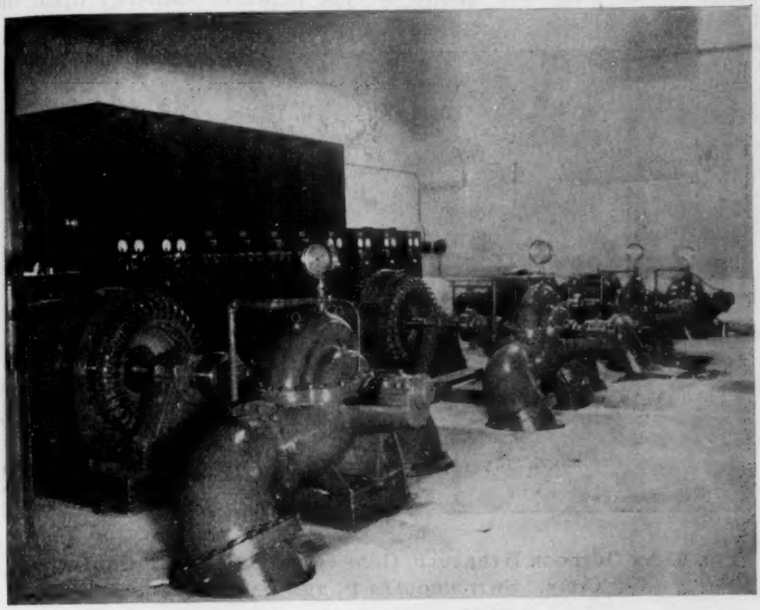

FIG. 5. OKLAHOMA CITY WATER WORKS SHOWING CUBICLE CONTROL EQUIPMENT FOR THE SYNCHRONOUS MOTORS

nearly as great as in power substations where interruption of service may be instantaneous and continuity of service is of utmost importance.

ENCLOSED PRIMARY SWITCHING STRUCTURES

Another suggestion for increasing the safety, reliability and ease of maintenance for pumping plants is the use of factory built metal enclosed primary switching structures. These are known as cubicles, trucks, and metal clad units (Fig. 5). Each is a complete unit of

circuit breaker and steel supporting structure, complete with bus and wiring connections, enclosed in a metal housing, all assembled and tested at the factory and shipped ready for instant use after bolting down and making the connections to the main leads and control wires.

In addition, these units permit of much more accurate estimates of cost on equipment and installation and the time required to complete the station, than when figuring on switchboards to be assembled and wired on the job. The choice of type depends primarily upon the

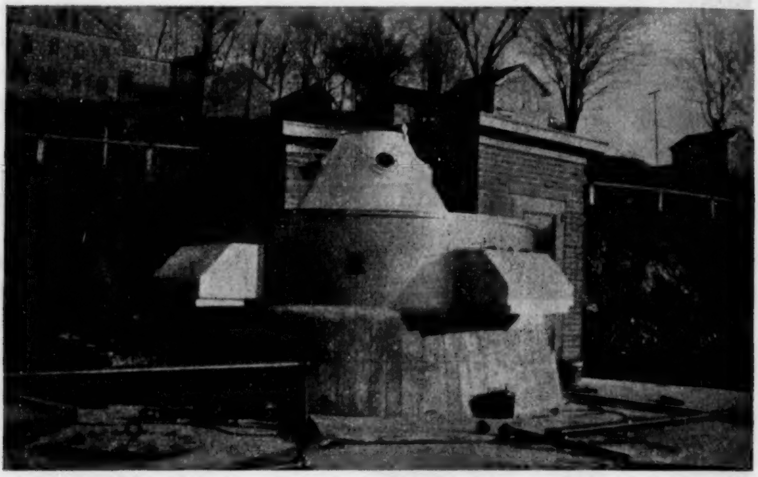

Fig. 6. An Outdoor Hydraulic Generating Station at Unionville, Conn. Switchhouses in the Background
1275 K-va. 257 RPM. generator

service, space requirements, and cost. Generally the cubicle or metal clad type unit should be selected.

OUTDOOR STATIONS

Another thought I would like to leave with you, as a means of lowering costs, is the use of outdoor pumping stations. Much has been done along this line in power substations and the like, with very satisfactory results. Although this may seem too radical to be considered seriously at this time, there would seem to be no serious difficulty in designing the pumps, as well as the motors and control

for outdoor service, or at least housing them with simple removable covers that are sufficiently lagged to prevent freezing of the pumps. If necessary, heaters, thermostatically controlled, could be included or the vertical pump and motor used with the pumps placed in a pit on a line with piping, so arranged as to be easily disconnected and removed for inspection and repairs.

With remote or supervisory control and outdoor switching equipment, the use of outdoor motor driven pumping units would reduce to a minimum the first cost, the installation cost and the operating cost.

(Presented before the Central States Section meeting, September 22, 1932.)

DISCUSSION

CHAIRMAN HIBBS: I think we can all appreciate Mr. Allen's paper when we consider the difficulties with which the oldtime waterworks superintendent had to contend when it came to designing pumping equipment. I am told that in the City of Cincinnati it was a foregone conclusion that each new superintendent was supposed to design the pumping equipment, and after a number of years the pumping station was known as "the old curiosity shop" to the engineers. Everything imaginable was used to pump water as a result of the various designs of equipment used by the different superintendents. Today standard equipment may be obtained, with plenty of bidders for the work.

Mr. Allen mentioned the type of long distance recording apparatus. Anyone who has gone into that has found that at the present time you can get five or six different types of instruments which will record water levels for long distances. The main feature of cost being, of course, the transmission lines.

In Akron, in 1925 and 1926, we designed an automatic radio system for sending water level records for a distance of ten miles from our reservoir to the pumping station. This would cut in each hour at five minutes of the hour, operating on a low wave length. I think it is still working. They had a Government permit for several years, but I am not sure whether they still have a permit or not.

MR. JOHN T. CAMPBELL: I should like to ask whether there has been anything developed in wireless control, or radio control along the lines as brought out by Chairman Hibbs?

Mr. R. C. Allen: There is no reason why it is not possible. Of course, it is more complicated and more costly, and possible interference from other sources would limit its use.

Today we have this control where it can be operated over other wires, such as high tension wires, and things of that sort, so there are ways of doing it besides this direct supervisory wire control.

Mr. Daniel E. Davis: I just wonder whether Mr. Allen was not expecting to get a little rise out of waterworks men in connection with the suggestion that some of this pumping equipment might be operated as outside equipment in a similar way as the large electric-substations are doing at the present time. He has covered some of the objections that would ordinarily arise in the minds of waterworks men, particularly in places where we have cold weather. Naturally protection must be given pumping equipment which stops during the day and is subject to freezing, and some provision must be made for housing or insulating it.

Actually we have had experiences which approach the suggestion Mr. Allen has made. I recall one home-made installation which was perhaps similar to the equipment mentioned by Chairman Hibbs a little while ago when he spoke of the old style pumping equipment in Cincinnati.

In this particular community there were a number of automatically operated pumps in connection with wells. The pumping unit was housed in a concrete chamber beneath the sidewalk and every few months something would go democratic and it would be necessary to re-wind the motors.

This suggestion by Mr. Allen would certainly be an indication that the electrical folks are more confident of their equipment than they were in the old days at least.

There is one element in the sending of messages, particularly in connection with sending of water elevations, of which you are all familiar, which permits the use of two wires of the telephone company for the transmission for considerable distances. Many of the transmitting arrangements are 3-wire arrangements, operating on AC current. However there are two or three companies that now put out both AC and DC equipment which can be operated on two wires, and permit the leasing of telephone circuits, simplifying the maintenance problem.

MR. N. B. JACOBS (of Morris Knowles, Inc., Pittsburgh, Pa.): Mr. Allen's paper is of interest not only to the designing engineer, but also the operator and water works officials, in that it is illustrative of all the various types of motorized pumping control which may be employed, and also because of the fact that it points out possibilities where economies may be effected. One of the problems for the water works man, whose plant is located in a community with irregular topography, is the question of supplying adequate pressure at high points. Much as we might like to, we are not able to stop real estate developments in localities where it is difficult to provide adequate pressure. Where many booster pumping stations are required in scattered locations, the question of supervision and attendance means an additional operating expense.

While full automatic stations are numerous, there is always the fear that something might go wrong and the lack of definite knowledge on the part of the superintendent, located in some central office, as to just what is happening in his booster station. The remote direct wire or supervisory control, as described by Mr. Allen, provides means for removing this uncertainty. These types of control are costly, however, and the advisability of employing any of them is a matter of economics, except for giving the proper weight to the intangible value of having the responsible man completely and reliably informed at all times.

The closing thought left by Mr. Allen of the outdoor pumping station, similar to the outdoor substation which has now become quite common among power companies, is of interest, because it also suggests a means of reducing original expenditures. This thought is now being developed for power plants and may be applicable to pumping stations, when all of the obstacles attendant thereto have been overcome.

WATER SOFTENING PLANT AT WESTERN SPRINGS, ILLINOIS

By Donald H. Maxwell

(Of Alvord, Burdick and Howson, Consulting Engineers, Chicago, Ill.)

On January 10, 1932, Western Springs, Illinois, began using softened water from the new municipal plant. This western suburb of Chicago obtains its water supply from two wells about 375 feet deep in the Niagara limestone, which yields a very hard water in this particular locality, the total hardness being 900 parts per million. Water is now delivered to the consumers iron-free and with a total hardness of about 125 parts per million. It is comparable for household use with filtered Lake Michigan water, and compares favorably with the better quality public water supplies of the central west.

The cost of softening is approximately 22 cents per 1000 gallons, including fixed charges, with the plant operating an average of three and one-half hours a day.

QUALITY OF WELL WATER

Typical analyses of the Western Springs well water are given in table 1.

These analyses show a non-carbonate hardness from 530 to 540 parts per million, which is nearly 60 percent of the average total hardness. The high iron content, 3.5 parts per million, makes the water particularly objectionable from the standpoint of staining of laundry and plumbing fixtures.

WATER TREATMENT INVESTIGATION

Prior to designing the treatment plant, experiments were made to help in determination of the best softening process to use. A complete model lime soda-ash softening plant was improvised, which included the following parts:

1. Aerator.
2. Constant level feed box for measuring water to softener.
3. Chemical dry feed machine.

4. Two mixing tanks, capacity 7 gallons each.
5. Two clarifiers, capacity 52 gallons each.
6. One carbonation tank, capacity 21 gallons.

The plant was arranged for sludge return to the mixing tanks. It was operated at a rate of 22 gallons per hour.

With this plant, it was demonstrated that an iron-free, good tasting, soft water could be obtained, but the apparatus for feeding chemical and the means for control of CO_2 were not sufficiently precise to permit of obtaining as consistent quantitative results as desirable for purposes of estimating the cost of softening. It was found necessary to resort to bottle experiments for precise determination of quantity of chemicals and time of settling required.

TABLE 1

	ANALYSIS BY ILLINOIS DEPARTMENT OF HEALTH, FEBRUARY 2, 1927	ANALYSIS BY CHAS. P. HOOVER, JUNE, 1930
Alkalinity	398	356
Non-carbonate hardness	531	540
Total hardness	929	896
Calcium	228	232
Magnesium	87	77
Iron as Fe	3.5	3.4
Anhydrous sulfuric acid	544	516
Chlorides as Cl	11	21
Free CO_2		82

The conclusions drawn from the experimental work were as follows:

1. 31 to 32 grains per gallon of quick lime and 30 grains of soda-ash would be required to produce a hardness of 100 parts per million.
2. The mixing time should be 30 minutes.
3. The settling period should be two hours as a minimum.

It was determined further that the water was especially well adapted to softening by the combined lime-zeolite process.

SELECTION OF PROCESS

Comparative estimates were made of investment required and the annual cost of four types of softening plant are set forth in table 2.

The plans above estimated are not strictly comparable in that plan "C" does not include any soft water storage, whereas the other plans provide 140,000 gallons storage.

Plan "A" was recommended as the best suited to the conditions at Western Springs and was adopted with the following plan of operation:

(a) Aerate.
(b) Rapid mix of lime and soda-ash, 5 minutes.
(c) Slow mix, 35 minutes.
(d) Settle, 2 hours and 20 minutes.
(e) Return part of sludge to rapid mixing tank.
(f) Carbonate, 24 minutes.
(g) Filter.

TABLE 2

Costs of various methods of treatment

	PLAN "A" LIME SODA 1 UNIT	PLAN "B" LIME SODA 2 UNITS	PLAN "C" LIME SODA RAILROAD TYPE	PLAN "D" LIME ZEOLITE
Investment	80,520	100,210	67,100	111,320
Annual cost—interest and depreciation	6,450 (at 8%)	8,000 (at 8%)	5,620 (at 8½%)	9,450 (at 8½%)
Operating expenses based on year 1929	14,640	14,140	14,640	12,900
Total Annual Cost	21,090	22,140	20,260	22,350

(Figures given are in dollars.)

PLANT DESIGN

Plant design was restricted by limitation of funds so that particular attention was given to economy and compactness of layout and provision for orderly expansion.

The plant is designed with a rated capacity of 1,500,000 gallons per 24 hours, with the above noted mixing, settling and carbonating periods.

The building exterior is designed for location closely adjoining a residence district. The upper floor is divided into meter shop, lavatory and chemical storage room. The latter provides space for two carloads of chemicals and two feed hoppers. It is served by a monorail with outside overhang and 0.5 ton electric hoist.

Chemical feed equipment, part of the motor control equipment, laboratory and filters are located on the main floor, from which access is had to the aerator and mixing, settling and carbonating basins which are immediately adjoining, but outdoors.

The main switchboard, pumps and carbonating and heating installations are located at basement level, the new well pump being housed beneath the front porch. The clear well is located under the filters and high lift pump pit and the wash water cistern outside in the corner between the carbonating room and the well pump room.

Aeration

The aerator consists of an aer-o-mix unit mounted on a deck over the carbonating basin with fountain discharge onto a baffled circular

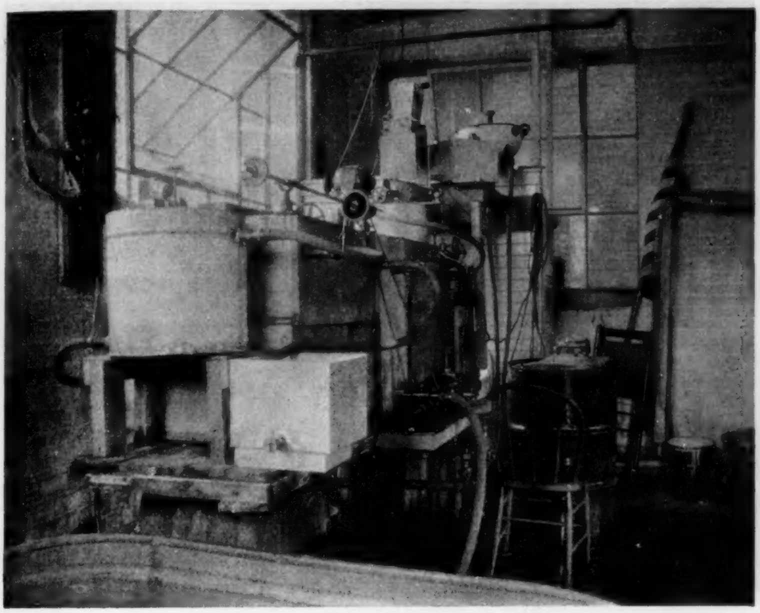

FIG. 1. EXPERIMENTAL WATER SOFTENING PLANT

splash plate. This device operates on about 7 feet head measured from inlet flow line to the raised splash plate and on a total head of 8½ feet to tail water under the splash plate. The equipment as first installed accomplished a CO_2 removal of about 50 per cent, but has been modified and is now reported to remove from 70 to 72 percent CO_2 and the manufacturers hope to further improve the performance. Payment is to be on the basis of CO_2 removal.

From the baffled plate, the aerated water falls onto a concrete pan from which it flows to a unit utilized as a rapid mixer in connection with the tank for that purpose over which it is installed.

Chemical feed

Slake lime and soda ash are fed by two automatic weighing and recording electric motor operated dry feed machines with slakers. Each machine has a feed range of 70 to 400 pounds of chemical per hour. The machines are enclosed dust tight. The charging hoppers and slakers are vented outdoors through a spray tank and exhaust fan which discharges downward under a platform on to the water surface of the rapid mix tank. The discharge from the two dry feed

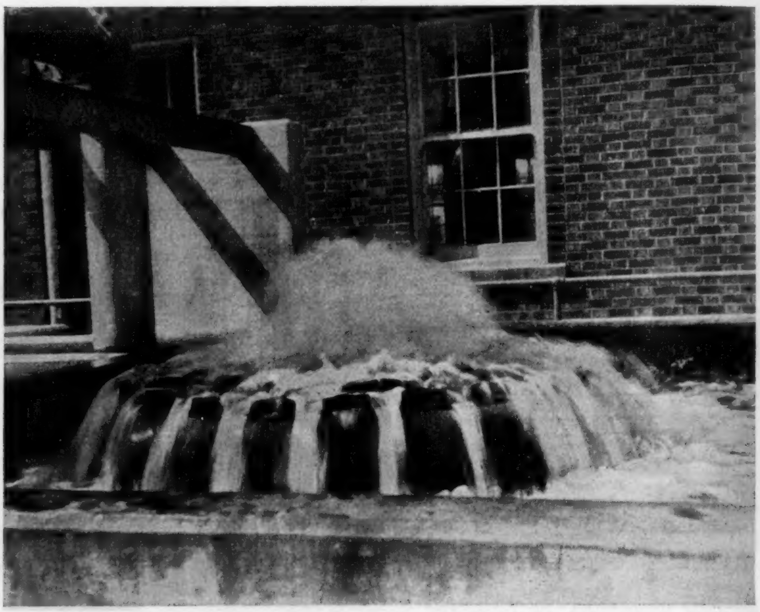

FIG. 2. DISCHARGE FROM AEROMIX AERATOR

machines flows into a small metal tank partly submerged in the rapid mixing tank, thence to the rapid mixer.

Rapid mix

The rapid mix tank is about $7\frac{1}{2}$ feet square by 12 feet deep. A second aer-o-mix unit is mounted over the rapid mix tank at the outlet end of the concrete aerator pan, and utilizes about $2\frac{1}{2}$ feet head. The aerated water enters this aeromix and after passing through the draft tube, where it is joined by the chemical solution, discharges at

the top of the rapid mix tank in which it produces considerable agitation.

Slow mix

Slow mixing is accomplished in a tank 19 feet square by 12 feet deep in which is mounted an impeller agitator. This consists of a motor driven two-vane impeller mounted on a central vertical shaft at about one-third depth in an upward flow concrete draft tube of 12 feet diameter. Three speeds are provided, 10, $12\frac{1}{2}$, and 15 R.P.M.

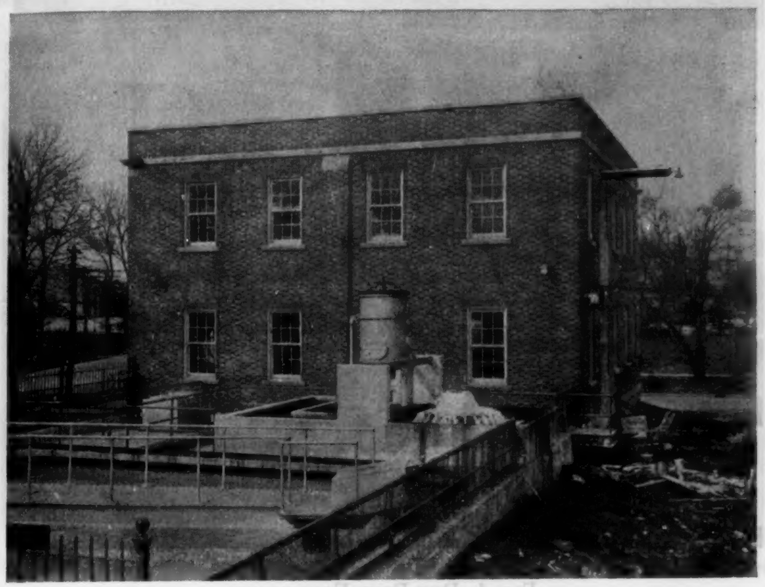

FIG. 3. AERATING, MIXING AND CLARIFIER EQUIPMENT

This equipment causes a radial loop flow in a vertical plane and gives a very thorough mix without violent agitation.

Clarifier

The slow mixing tank discharges directly to the clarifier influent channel. The clarifier or settling tank is 40 feet square by about 12 feet deep, equipped with a traction clarifier. The influent trough has an adjustable metal lip to provide uniform distribution of inflow and the inlet and outlet weirs are baffled to give better vertical dis-

tribution of flow across the tank. The clarifier operates at a peripheral speed of $6\frac{1}{4}$ feet per minute.

The sludge outlet is piped to the pump room where it passes through a sight-feed from which it either runs directly by gravity to the sewer or to the sludge pump for return to the mixing tank. The plant is now being operated without returning any sludge. A valve above the sight-feed permits of regulation of the rate of sludge discharge to the sewer, to avoid unnecessary waste of water.

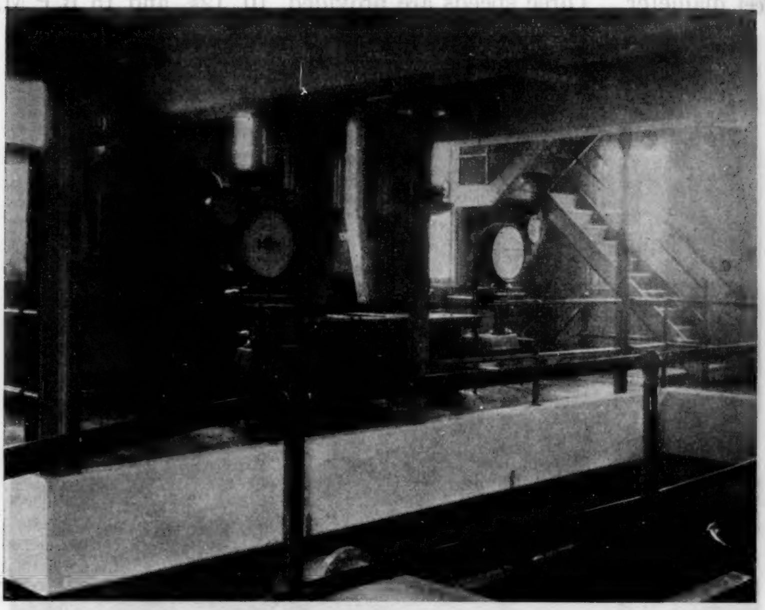

FIG. 4. DRY FEED EQUIPMENT

Carbonating basin

Carbonation takes place in an L shaped basin 12 feet deep and about $10\frac{1}{2}$ feet average width by 27 feet long, located under the aerator pan. CO_2 gas is introduced through a pipe grid placed at the tank bottom. The grid is made of $\frac{3}{4}$-inch pipe with $\frac{1}{16}$-inch holes 6 inches centers on the under side and placed $2\frac{1}{2}$ feet apart on top of $\frac{3}{4}$-inch sill pipes laid on the basin floor.

CO_2 generating plant

CO_2 gas is supplied from the stack of the coke or coal fired steam boiler of the plant heating system. The boiler is equipped with an

automatic stoker, which has been used since the plant went into operation, burning coke. The abrasive action of the coke has been destructive of the screw conveyor feed, but it is understood that the manufacturers are taking steps to remedy this defect. The stoker has three speeds, 10, 20 and 30 pounds of fuel per hour. The slowest speed is used when the heater is run for CO_2 alone and the higher speeds for heating. The stoker provides good fuel and draft control and has been found very satisfactory in connection with CO_2 production, the installation showing results as high as 17 per cent CO_2 continuously when burning coke.

FIG. 5. WATER SOFTENING AND IRON REMOVAL PLANT, WESTERN SPRINGS, ILL.

Automatic control of stoker protects the boiler against low water excess pressure and excess exit gas temperature. For winter operation, when heating the plant, the stoker feed is thermostat controlled and pressure regulated between 2 and 4 pounds pressure. When the plant is running but heat not required, steam is by-passed to a condenser through a regulating valve set at 3 pounds. The condenser circulating water is returned to the clear well and condensate returned to the boiler. When the plant is not operating, control of the heating boiler is regulated by an adjustable time-o-stat which is set to operate 10 minutes every hour, this having been found about right to keep the fire alive.

The gases are cooled from 500° to 100°F. in a built-in brick lined

scrubber, the circulating water from which is delivered by a bilge pump to the wash water cistern. The cooled gases are delivered from the scrubber against the 12 feet head on the carbonating basin grid by a motor driven rotary compressor, which stops automatically if the CO_2 supply is shut off. A meter records the CO_2 production in percent and pounds per hour.

Filters

Two 750,000 gallons per day rated capacity sand filters are provided, of conventional construction, but rated at 3 gallons per square foot per minute. Valves are manually operated. The filters form one side of the pump pit, which also serves as a pipe gallery. The wash system is designed for 24 inches vertical rise per minute, no provision being necessary for increasing the wash rate in summer as the water temperature remains practically constant at 55°. The laterals are 2-inch cast iron with $\frac{3}{8}$-inch perforations 6 inches centers. The gravel layer, carefully graded, extends 21 inches above the center line of the laterals. Next comes a 4 inch layer of No. 2 torpedo sand, followed by 26 inches of filter sand having an effective size of 0.45 to 0.50 millimeters and a uniformity coefficient between 1.3 and 1.6.

High lift pumps

The three 500 gallon per minute high lift motor driven centrifugal pumps take suction from the clear well located beneath the filters and pump pit. Each pump is connected to an overhead vacuum tank which is piped to bottom of the clear well and to a rotary vacuum pump controlled by a float switch. The main pumps are protected against failure to prime and an empty clear well. Equipment is now being added to give a plant alarm of full clear well and an alarm at the village hall when the clear well is empty.

The high lift pump control is mounted on the main switchboard, of the dead front type, located in the pump pit. Manual and separate automatic pressure control is provided for each pump. In normal operation one pump shuts off at tank full pressure and starts on a 10 foot lower level. The next pump stops at this level and starts on a level 10 foot lower and so on for the third pump. A sequence changer makes it possible to use the pumps in any order.

With this arrangement three-quarters of the elevated tank capacity is kept in reserve at all ordinary times. Any unusual draft is promptly replenished from the clear well, without the necessity of having an operator at the plant.

Arrangement for washing filters

The same pumps are used for washing the filters, which requires a flow of 2,600 gallons per minute. This rate is supplied by the pumps operating at about 90 feet total head at which point the efficiency is only 5 points below the maximum.

Before washing, the main discharge valve to the distribution system is closed and the valve to the wash line opened. As the filter wash valve is opened the pumps start up in succession automatically as the pressure drops. Upon closing the filter wash valve the pumps shut off in the reverse order with rising pressure. This arrangement of washing directly with the pumps is convenient and has the advantage of not depleting the elevated storage. It slightly reduces the cost of wash water due to lower head pumped against.

Wash water and CO_2 scrubber circulating water are reclaimed in a cistern and repumped automatically to the rapid mixing tank by a 100 gallon per minute pump, the sludge being removed in the clarifier.

OPERATING SCHEDULE

At present, pumpage requirements are being supplied by running the low lift (deep well) pumps and softening plant an average of about 4 hours, usually two hours morning and evening, the clear well being filled each time. Both wells are utilized, supplying sufficient water to run the plant almost exactly at rated capacity. Plant attendance is not provided at other times except as incidental work may require.

Better results could probably be obtained by operating the plant at about half capacity by pumping one well instead of two and operating for about twice as long each day as on the present schedule. This would nearly double the reaction and settling periods and reduce the load on the filters. Sensitiveness of the aeromix to change in rate and inability to handle the wide range with a single machine will probably give lower efficiency of aeration. Otherwise the plant has considerable flexibility.

PRACTICAL BENEFITS

It is reported that about 40 percent of the homes in Western Springs had zeolite softeners. Others had cisterns. These facilities did not do away with the staining of fixtures and it is estimated that the annual cost of zeolite softeners and cleaning compounds for the average household was considerably in excess of the present increased cost of city water due to the necessary doubling of rates. Although

the plant has been in operation only three months so that conditions, including the distribution system, do not yet show the full advantages that will be had ultimately, there is considerable satisfaction with the results and people are showing a tendency to dispose of individual zeolite softeners. It is stated that a single store reported a falling off in sales of sani-flush from 180 cans during the week before the plant started to only 14 cans in the month following.

It is too early to draw conclusions as to the effect of the improved quality of water on water consumption.

PLANT COST

The iron removal and water softening plant cost complete except land and new deep well and pump for same but including 150 feet of 8-inch pipe laid under railroad tracks and about 500 feet of 12-inch cast iron discharge line, a total of about $98,000. This includes engineering and $2,625 interest during construction. The work was financed under the water revenue bond act of 1927, the bond issue for the improvement being $110,000.

ACKNOWLEDGMENT

Mr. Charles P. Hoover, as consulting chemist, supervised the preliminary investigations in coöperation with the writer's firm. The model softening plant was loaned to the Village by the Dorr Company who also furnished the services of an operator.

A number of features in the plant are due to S. M. Hull, member of the Village Board of Trustees, and an industrial chemist of wide experience, who devoted much detailed attention to design, selection of equipment and construction, and who now supervises operation.

The aerating devices were furnished by Vogt Bros. Company; feed machines by the Omega Machine Co. and the impeller agitator and clarifier by the Dorr Company.

Acknowledgment is also due to G. F. Graham, Village Engineer, who supervised the construction and to the Burnip Construction Company, general contractors, for the very satisfactory execution of the construction.

The plans and specifications for the plant and the preliminary report and estimates were made by the writer's firm, in coöperation with Mr. Hoover.

(Presented before the Illinois Section meeting, April 12, 1932.)

GROUND WATER SANITATION AT HOUSTON, TEXAS

By J. A. Sauls, Jr., and Clyde R. Harvill

(Chief Water Works Engineer and Water Works Sanitary Engineer, Houston, Texas)

Houston, Texas, with a population of 292,352, according to the 1930 Census, is the largest City in the United States depending entirely upon ground water for its municipal water supply. This fact has afforded excellent opportunity for the study of the quality of ground water and the factors that influence the sanitary quality of this type of supply. The purpose of this article is to show from actual data, accumulated over a period of years, just what can be expected from wells in this area, particularly from the viewpoint of sanitation. The data presented are the result of an intensive study of the sanitary quality of ground water, initiated and carried out by the Engineering Division of the Water Department of the City of Houston as part of its operating program.

The underground water at Houston is drawn from unconsolidated sands probably of the Pleistocene and Pliocene series. The water bearing formations are known locally as Lissie and Reynosa and consist essentially of sands, clays and shales laid down in more or less thin beds. Although these beds vary a great deal in thickness from place to place the major sands are probably continuous throughout the area. The dip is in a southeasterly direction about 35 feet to the mile and the strike is about north 45 degrees east. The alternate beds of sand and impervious clay due to their inclined positions give rise to many artesian conditions. A strip along the Gulf extending inland about 15 miles north of Houston is covered with a formation of predominantly clay (Beaumont Clay) that also serves as a splendid restraining formation to prevent the upward escape of water from the water bearing sands of the deeper Lissie and Reynosa formations.

Mechanical analyses of these sands show that about 25 percent of the sand grains are between 0.50 and 0.25 millimeters in diameter; about 50 percent between 0.25 and 0.125 millimeters and about 15 percent between 0.125 and 0.062 millimeters in diameter. The other

10 percent are above and below these limits. A total of as much as 500 feet of water bearing sand is penetrated with the drill between 300 and 1850 feet below the surface. The sands crop out 15 to 50 miles northwest of Houston. The outcrop area of the water bearing sands supplying Houston has an average rainfall of 45 inches each year. As the rain falls upon the ground a large part of it runs off or evaporates, but much of it seeps into the underground beds of sand and begins its slow journey from the dip toward the Gulf. The movement of ground water through sand, in contrast with movement through open cracks and solution channels, is extremely slow. It has been estimated that the water moving from the outcrop toward the Gulf by way of the water bearing sands travels about 200 feet a year or roughly from 0.5 to 1.0 foot a day. No matter how the movement of ground water is estimated it is a matter of hundreds of years from the time the water falls as rain until it is pumped from wells at Houston.

CITY WELLS

The water wells in Houston and vicinity may be placed under three headings, drilled, bored and dug. The bored and dug wells are very shallow and are not used for public and semi-public supplies and, therefore, it is in the first of these types of wells in which we are most interested. The drilled have been classed as City and private because of the differences in construction and supervision between the city and private wells.

The City draws its water from 31 wells, in eight widely separated well areas (figure 1). The wells range in depth from 250 to 1900 feet. The newer wells are of the latest type of construction known to rotary drilling and are not only rigidly supervised during construction, but are very closely watched during their operating life for mechanical, as well as sanitary failures. The older wells were drilled at a time when the requirements were less rigid and there is no doubt that much carelessness existed during their construction. However, the surroundings of these wells, have been so improved as to place their operation and supervision on the same plane with the newer ones. All of the newer wells are 12 inches in diameter with a 300 foot pumping pit of 24-inch welded round plate. The annular space between the bottom of the pump pit and the top of the 12-inch casing is sealed with 10 feet of concrete in order to prevent any seepage or cavings from entering the well at this point. These wells are drilled with a rotary rig to a

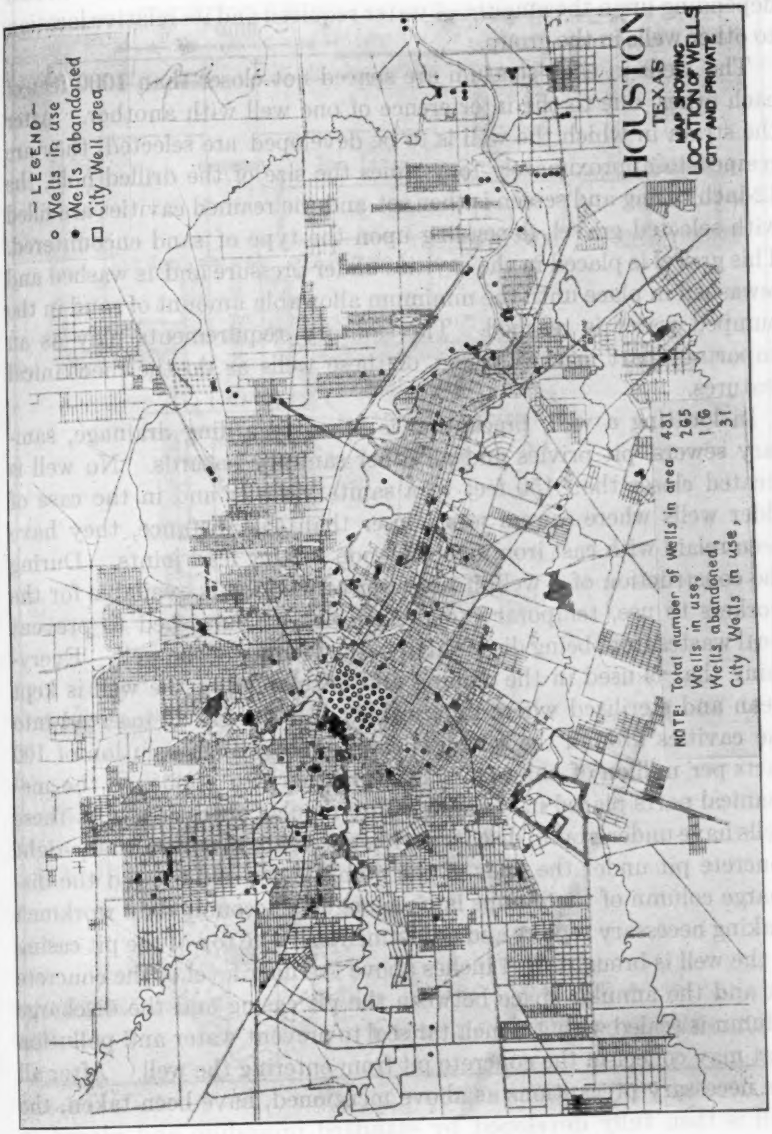
LEGEND
Wells in use
Wells abandoned
City Well area
HOUSTON
TEXAS
MAP SHOWING
LOCATION OF WELLS
CITY AND PRIVATE
NOTE: Total number of Wells in area 481
Wells in use, 265
Wells abandoned, 116
City Wells in use, 31

FIG. 1

depth of at least 2100 feet and the necessary sand strata selected depending upon the amount of water required and its relative location to other wells in the group.

The wells in each stratum are spaced not closer than 1000 feet of each other, due to the interference of one well with another. After the strata in which the well is to be developed are selected, they are reamed to approximately four times the size of the drilled hole, the 12-inch casing and screen is then set and the reamed cavities are filled with selected gravel, depending upon the type of sand encountered. This gravel is placed in the cavities under pressure and is washed and rewashed in place until the minimum allowable amount of sand in the pumped water is reached. The sanitary requirements play as an important part in the drilling of these wells as do the mechanical features.

In locating a well, precaution is taken regarding drainage, sanitary sewers, pit privies and all other sanitary hazards. No well is located closer than 150 feet to a sanitary sewer and in the case of older wells where sewers were closer than this distance, they have been relaid with cast iron pipe with non leaking lead joints. During the construction of a well, if no sewer connection is available for the workers to use, temporary toilet facilities are furnished to prevent fecal wastes from being distributed in the vicinity of the well. Everything that is used in the drilling and developing of the well is kept clean and sterilized where practicable. All the gravel inserted into the cavities around the screen is chlorinated with a solution of 100 parts per million of chlorine. This practice also applies to the mechanical parts placed in the well before regular operation. As these wells have underground discharges it is necessary to build a water-tight concrete pit under the floor of the pump house and around the discharge column of the pumps large enough to accommodate workmen making necessary repairs and adjustments. The top of the pit casing of the well is brought up 4 inches above the floor level of the concrete pit and the annular space between the pit casing and the discharge column is sealed with a 6-inch tar seal to prevent water and pollution that may collect in the concrete pit from entering the well. After all the necessary precautions as above mentioned, have been taken, the well is then fully developed by standard procedure and placed in service (see figure 2).

All wells in the city system are pumped by deep well turbines of a standard make with underground discharges with the exception of 10

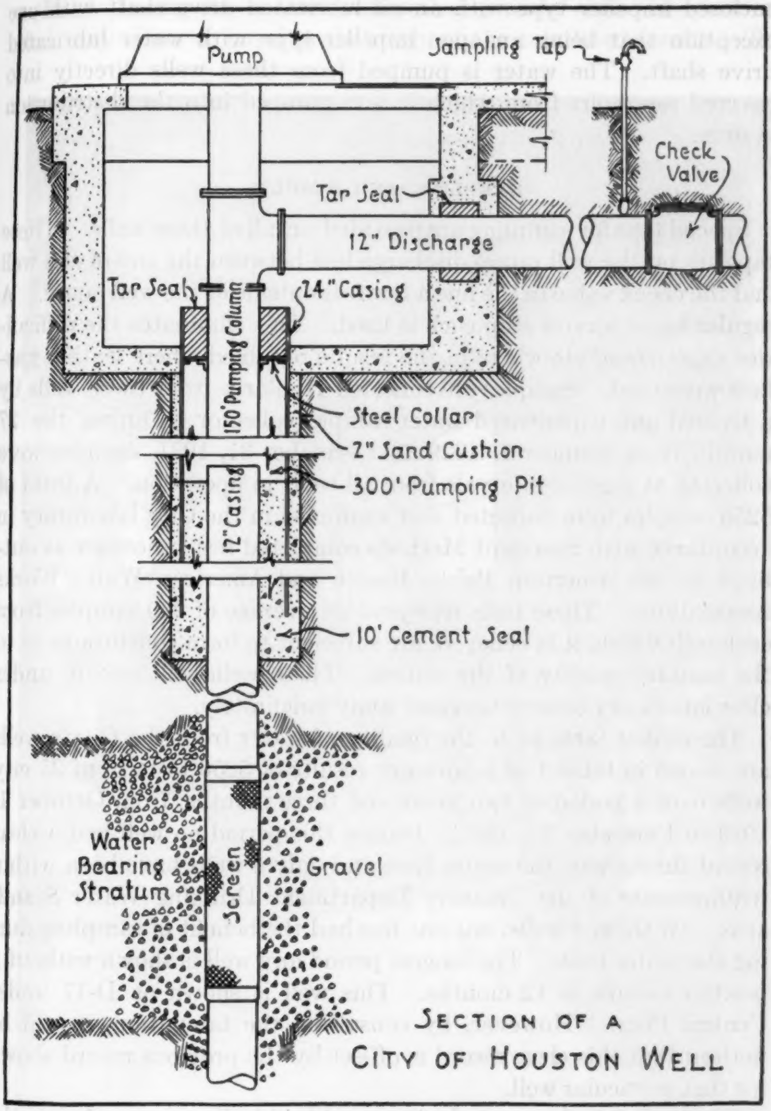

FIG. 2

wells at the central plant which are pumped by air. These air lift wells are used, however, only in an emergency and do not play a very important part in the system. The deep well turbines are all of the

enclosed impeller type with an oil lubricated drive shaft with one exception that being an open impeller type with water lubricated drive shaft. The water is pumped from these wells directly into covered reservoirs from which it is re-pumped into the distribution system.

SAMPLING AND RESULTS

Special taps for sampling are provided on all of these wells. These taps are on the well pump discharge line between the top of the well and the check valve in the line a few feet outside of the well house. A regular brass service stop cock is used. This eliminates the difficulties experienced elsewhere in the results obtained where leather gaskets were used. Samples are collected regularly from these wells by a trained and experienced water sample collector. During the 27 months from October 1, 1929 to December 31, 1931, samples were collected at regular intervals from all wells in operation. A total of 5256 samples were collected and examined in the City laboratory in accordance with Standard Methods completed test procedure as outlined by the American Public Health and American Water Works Associations. These tests represent an average of 250 samples from each well which, it is believed, are sufficient to form conclusions as to the sanitary quality of the waters. These wells will remain under close laboratory observation and study indefinitely.

The salient facts as to the quality of water from the City's wells are shown in table 1 of laboratory results of 5256 tests from 25 city wells over a period of two years and three months, from October 1, 1929 to December 31, 1931. During this period no well had a clear record throughout the entire time and only 4 wells have been within requirements of the Treasury Department Drinking Water Standards. Of these 4 wells, not one has had the benefit of sampling during the entire time. The longest period any well is shown without a positive sample is 12 months. This well is shown as D-17 under Central Plant. However, by consulting the tabulation, it will be noticed that this clear record is off-set by the previous record shown for that particular well.

The B. Coli Index or "index" as used in this discussion refers to the percentage of 10 cc. portions showing evidence of the presence of organisms of the Coli-Aerogenes group. The allowable limit of which is 10 percent as specified by the Treasury Department Drinking Water Standards.

The following explanation will probably make clear the questions that may come to mind in the study of the tabulated results. The

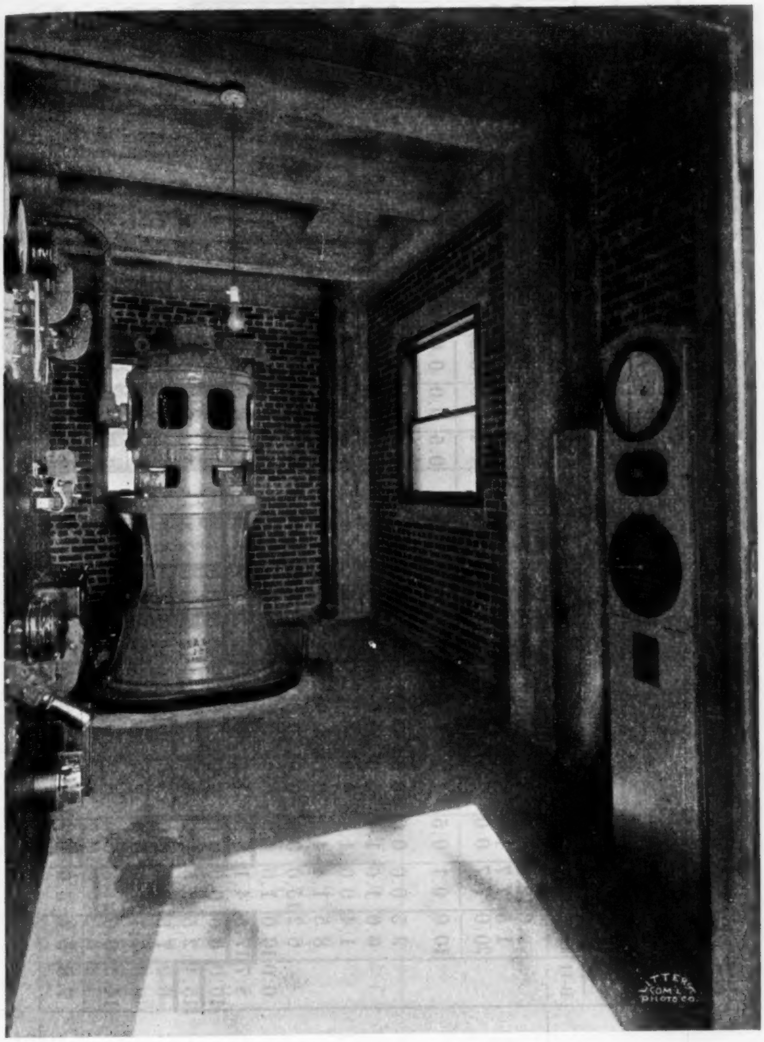

FIG. 3. INTERIOR VIEW OF A TYPICAL WELL HOUSE, CITY OF HOUSTON, TEXAS

Magnolia Park Well No. 1, during April, 1930 had an index of 85 percent and in May an index of 30 percent, in March it was clear and

TABLE 1

Percent of 10 cc. portions confirming positive for Coli-aerogenes group in supply wells

YEAR	MONTH	CENTRAL						SOUTH END					SCOTT ST.				HEIGHTS			MAGNOLIA PARK		WEST END		NORTH SIDE		EAST END
		Well numbers																								
		B-11	C-16	D-17	F-1	F-5	F-10	1	2	3	4	5	1	2	3	4	2	3	5	1	2	1	2	1	2	1
1929	October		9.0	12.0	0.0	1.2	0.0	2.0	1.8	0.0	7.0		0.0	0.0	0.0		13.7	1.0		5.0	11.5	2.0	3.0	2.0	5.0	
	November		1.5	7.7	1.5			0.0		0.0	0.0		0.0	0.0	0.0		10.0	0.0		1.4	17.1	0.0	1.4	0.0	1.4	
	December		20.0	7.7	0.0			0.0		0.0	0.0		1.4	0.0	0.0		0.0	0.0		5.7	11.4	0.0	0.0	0.0	0.0	
	Average		10.0	9.1	0.5	1.2	0.0	0.7	1.8	0.0	2.3		0.5	0.0	0.0		7.9	0.3		4.0	13.3	0.7	1.1	0.7	2.1	
1930	January		3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	1.2		0.0	0.0		2.5	6.2	0.0	0.0	0.0	0.0	
	February		0.0	1.6	1.4	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		11.1	8.2		18.0	21.8	0.0	0.0	0.0	0.0	
	March		1.4	0.0	1.4	0.0		9.3	0.0	0.0	0.0		1.4	10.6	1.3		0.0	0.0		0.0	37.3	0.0	7.1	0.0	0.0	
	April		8.5	1.4	4.0	0.0	0.0	6.2	1.2	0.0	0.0		8.7	16.2	0.0		0.0	0.0		85.0	50.0	0.0	0.0	0.0	1.2	
	May		6.2	15.0	0.0	0.0	0.0	2.5	2.5	0.0	3.7		6.2	11.5	0.0		1.5	0.0		30.7	1.2	1.2	0.0	1.2	5.0	
	June	0.0	10.0	1.0	4.0	0.0	0.0	3.7	2.5	0.0	0.0		0.0	0.0	1.2		0.0	0.0		0.0	6.2	0.0	2.5	2.5	0.0	
	July	8.7	17.5	4.1	8.5	1.3	0.0	6.2	22.5	1.2	11.2		1.2	0.0	1.2		10.0	2.5		1.2	5.0	2.5	4.0	1.2	1.2	
	August	10.0	0.0	0.0	0.0	0.0	0.0	1.2	20.0	0.0	1.2		0.0	2.5	0.0		0.0	0.0		1.3	0.0	6.2	0.0	6.2	0.0	
	September	15.4	2.5	3.5	1.2	1.2	8.5	1.1	12.9	0.0	2.3		0.0	12.9	0.0		2.3	3.5		7.0	1.1	0.0	0.0	1.1	0.0	
	October	6.2	7.5	7.5	0.0	3.0	2.2	0.0	10.0	1.2	0.0		2.5	3.7	8.7		12.5	0.0		1.2	0.0	0.0	0.0	2.5	6.2	
	November	0.0	7.1	11.4	0.0	2.0	0.0	2.8	0.0	0.0	0.0		2.8	0.0	0.0		3.3	0.0		0.0	0.0	0.0	5.7	10.0	0.0	
	December	14.5	0.0	21.3	0.0	0.0	0.0	2.8	0.0	0.0	2.8		6.2	0.0	1.2		9.3	6.2		6.6	0 0	0.0	3.7	27.5	6.2	
	Average	7.8	5.4	5.6	1.7	0.6	1.0	3.0	6.0	0.2	1.8		2.4	4.8	1.2		4.2	1.7		12.8	10.7	0.8	1.9	4.4	1.7	

1931	January	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0		5.1	7.5	0.0		0.0	0.0		0.0	1.2	0.0	0.0	23.7	0.0	1.0
	February	0.0	2.8	0.0	0.0	0.0	0.0	6.6	0.0	1.3	0.0		0.0	0.0	2.6		0.0	1.3		0.0	0.0	4.0	1.3	2.6	2.6	0.0
	March	3.3	0.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	3.3		6.6	3.3	0.0	0.0	0.0	0.0	0.0
	April	0.0	4.0	0.0	50.0	100.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0			0.0	100.0	0.0	0.0	8.0	0 0
	May	10.0	0.0	0.0	0.0	0.0	100.0		5.0	15.0	0.0		0.0	0.0	50.0	97.5	0.0	0.0			0.0	33.3	0.0	0.0	5.0	0.8
	June	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0			6.6	0.0	60.0	0.0	0.0			0.0	20.0	0.0	0.0	0.0	1.0
	July	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	4.0			5.0	0.0	3.7	10.0	0.0	0.0		0.0	25.0	20.0	0.0	30.0	0.0
	August	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	10.0			0.0	0.0	6.6	0.0	0.0	0.0		0.0	5.0	0.0	0.0	0.0	5.0
	September		0.0	0.0	0.0	15.0	0.0		0.0	0.0	0.0	58.3		0.0	8.0	0.0		0.0	2.5		0.0	0.0	0.0	0.0	2.5	4.1
	October		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	2.5		0.0	0.0	0.0		5.0	0.0		0.0	0.0	0.0	0.0	0.0	0.8
	November		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	1.5		0.0	0.0	26.0	0.0	30.0	5.0		0.0	0.0	0.0	0.0	0.0	1.7
	December		0.0	0.0					0.0	0.0	0.0	0.0		28.0	4.0	0.0	0.0	60.0	0.0		0.0	0.0	0.0	0.0	10.0	0.0
	Average	1.7	0.5	0.0	6.0	10.5	9.2	2.2	0.4	1.4	1.1	15.6	1.0	3.9	5.4	16.1	0.8	8.3	1.2	2.2	0.3	15.6	1.8	2.2	4.8	1.2

before March, with the exception of February it was well within the allowable limits. This polluted condition was caused by reworking this well during April and although evey precaution was taken to prevent contamination, one can readily see from the results how unsuccessful these were. After the repairs to this well were completed, it required practically two months to bring its index to that allowable. The same conditions as explained above apply to Magnolia Park Well No. 2. Reworking of this well started in February, 1930, and it was not until the first part of May, 1930 that its index could be lowered to that allowable. This is quite significant, in view of the fact that the pumpage and waste of water along with the health hazards in clearing the wells probably amounts to more in dollars and cents than the cost of the treatment necessary to make the water immediately potable. In making this statement, reference to the unprotected private supply is intended rather than to the city supply which is amply protected against such possibilities. The other wells included in the tabulation showing high indices after being reworked, are Wells F-1 April, 1931; Well F-5 April, 1931; Well F-10 May, 1931; Scott Street Well No. 3 May, 1931; West End Well No. 1 April, 1931. These showed practically the same conditions after reworking as were brought out by Magnolia Park Wells Nos. 1 and 2.

A difficult question to answer is, why do several of the older wells stay well within the allowable limits for months and then suddenly show heavy pollution? The best the writers can suggest is that this phenomenon is a characteristic possessed by every well in the Houston system. Having been unable to determine the cause of his condition, anything said regarding it would be merely hypothetical. However, the water does show intermittent pollution and should be treated until such time as the cause may be determined and a solution for its elimination found.

Of the 5256 samples examined, 440 or 8.37 percent of the total were positive for the Coli-Aerogenes group. In the 440 positive samples, 358 or 81.36 percent were B. Aerogenes while 82 or 18.64 percent were B. Coli. The writers believe that the presence of B. Aerogenes in well water is of much significance, because it shows the presence of contamination and they feel that differentiation between bacilli in the group should certainly not be made as far as well supplies are concerned.

Season, rainfall and temperature appear to have no bearing on the results. Different wells show excessive pollution at different times of

the year. This would eliminate seasonal factors. Rainy periods at Houston predominate in the winter and spring and as the tabulation shows as many wells with high indices in the summer as in the winter and spring, rainfall factors would seem to be eliminated. The above conditions would naturally eliminate temperature as this cause would run parallel with the seasonal and rainfall causes. The wide variation of the high indices during 1930 and 1931 should clear up the question as to what effect the seasons, rainfall and temperature might have on these results. The high indices not considered were for cases where wells had been reworked and therefore would not be representative.

Wells, Central B-11 South End No. 1; South End No. 5; Scott Street No. 1; Scott Street No. 4; Heights No. 5; Magnolia Park No. 1 and East End No. 1 were not sampled throughout the entire time because Central B-11 was an old air lift well, converted into electric driven pump in June, 1930 and its casing collapsed during August, 1931. South End Well No. 1 was an old well that failed during April, 1931 after fifteen years of service. South End No. 5 is a new well, completed in September, 1931 to replace South End No. 1. Scott Street No. 1 developed mechanical defects in May, 1931. Scott Street No. 4 is a new well, put into service during May, 1931. Heights No. 5 is also a new well, put in service during July, 1931. Magnolia Park No. 1 developed well and pump trouble and was abandoned during April, 1931. East End is a new well completed and placed into service during January, 1931.

Probably the most important question to arise would be; What is the relation of the tabulated indices of one well with another in the same group through strata interference? All the newer wells in each group are so spaced as to avoid interference as no well is drilled closer than 1000 feet to another well taking water from the same stratum. This distance is estimated to be outside a well's cone of interference in this area. However, several of the older wells are only a few feet apart and interference might be inferred from table 1 by comparing several of the results obtained from Magnolia Park wells Nos. 1 and 2, which are approximately 100 feet apart. Well No. 2 was reworked during February, 1930 and this might account for the high index on No. 1 for the same month. However, this is hypothetical and should not be used without further test and study as they do not compare in this relation from month to month.

Another question of importance would be; What is the relation of one group of wells to another? The system is divided into 8 well

groups or areas, ranging in distance of from 2 to 8 miles apart, that is, the two stations closest together are 2 miles apart while the farthest any one station is from its closest neighbor is 8 miles. The sanitary

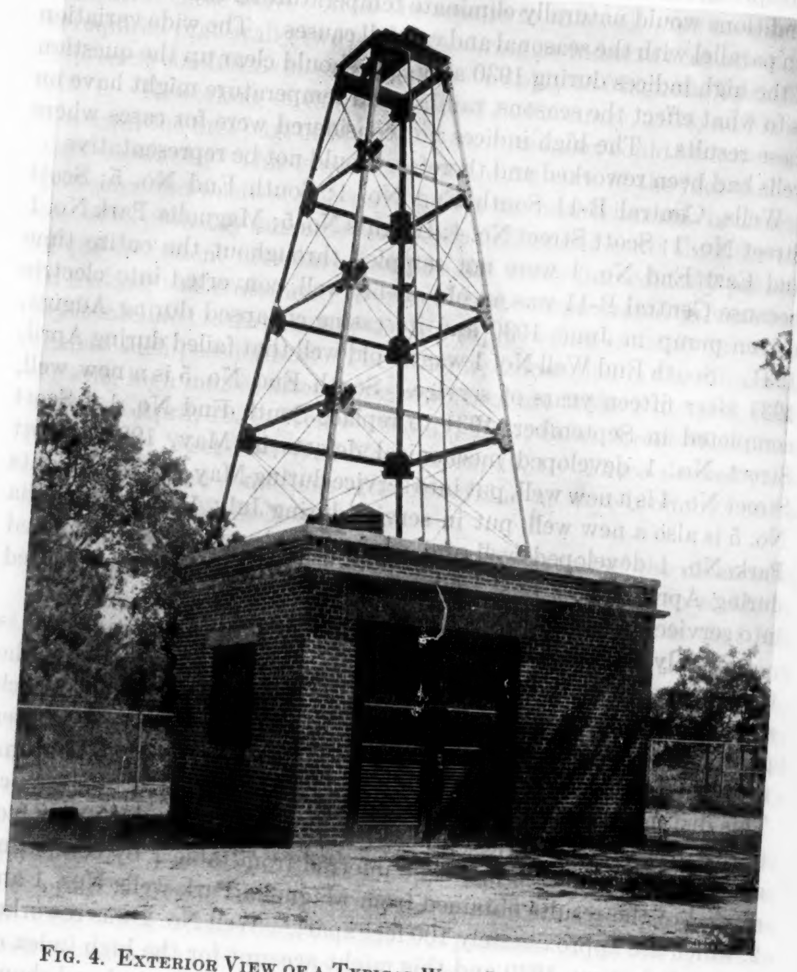

FIG. 4. EXTERIOR VIEW OF A TYPICAL WELL INSTALLATION, CITY OF HOUSTON, TEXAS

surroundings of each group are on a par with each other, being the highest obtainable. In each group, the wells range in depth from 250 to 1850 feet and are all of the same type and construction. The

pumps, method of sampling, and operation are the same in each group and have been explained in more detail heretofore in this discussion. It can readily be seen that none of the above factors would have important bearing on the results shown in table 1.

PRIVATE WELLS

Approximately 450 private water wells have been drilled in the "Greater Houston" area. They are widely scattered, but are more closely spaced in the downtown area where they serve office buildings, hotels, laundries, ice plants, etc. These wells, as a rule are not more than 900 feet deep and have been, without exception, drilled with rotary well drilling equipment. The screen and the entire casing are usually made up into a solid string of pipe. Sometimes the annular space between the casing and the hole is sealed with concrete, but usually it is left open. The concrete floor around some of these wells does not prevent surface water from flowing down into the well on the outside of the casing. In some of the better constructed wells, a larger annular space is provided in the water bearing sand and this is later filled with gravel. In these wells an attempt is usually made to seal the annular space with concrete at the top of the gravel or on the outside of the casing at the first reduction in size. Heretofore, vigorous pumping of a completed well was considered ample protection against pollution incident to construction and no wells were sterilized. The construction of these private wells is not standard and much lack of care has prevailed in their drilling. Generally speaking, very little attention is given the sanitary surroundings in selecting the location for a private well, but instead the interests are mainly governed by its accessibility for service and fire protection. This being a fact the private wells in downtown Houston have been in most cases drilled under sidewalks and streets without any attention to sanitary hazards. In this area, where the private wells are grouped closely together, every street has a large sanitary sewer and building connections to these sewers are built of concrete or clay pipe and do not have water tight joints. In many instances, private wells have been located and drilled only a few feet from these sewers. The wells drilled under the sidewalks and streets are covered with ordinary manhole covers with ventilated lids which permit overflow from sewers, drainage gutters, etc., to enter the wells that are not properly sealed, a condition that is not uncommon.

Where airlifts are used for pumping these wells, not much consider-

ation has been given to the source of the air supply. In most cases, it comes from the basement floor, engine rooms, or wherever the compressor may be located. In one instance, the air intake was

Fig. 5. Photographs Showing Casing Pulled from a Well Supplying an Office Building in Downtown Area

The holes shown were in the first two joints

raised so as to take air right off of the sidewalk on a busy street. About 85 percent of these private wells are pumped by air, 13 per-

cent by deep well turbine pumps, while 2 percent are pumped with old time jack pumps.

Sampling of private wells has been irregular in Houston and samples have been taken only in cases of cross connection surveys and at request of the owners or the State Health Department. However, quite a few samples have been examined and 163 samples have been collected from 13 private supplies. They show conclusively that supplies should be provided with the necessary treatment to bring them within the acceptable standards. In studying these results it will be noted that of the 13 supplies, only one has had results that come within the allowable standards. The others have indices that should prohibit their use under existing conditions. The water from some of these wells is used by Interstate Carriers. It is conservatively estimated that from 75,000 to 100,000 persons drink water from private supplies daily in Houston. In the opinion of the writers the laxity in drilling and operating private wells in this area is a serious problem and should at least be controlled by treating the water used from them.

ABANDONED WELLS

There are 116 known abandoned wells in the "Greater Houston" area. A large number of these wells were probably abandoned because of casing or screen troubles which reduced the flow below the point of economical production. All abandoned wells are potentially a source of danger unless properly sealed. Of the entire number of known abandoned wells, only 7 are known to be properly sealed so as to protect the underground strata from possible contamination. The possibilities of contaminating the underground strata from this source is well brought out in the case of an abandoned well that is used as a drain for the entire basement of a hotel in the downtown district where private wells are very close together. Another case is that of a group of abandoned wells within the banks of a heavily polluted bayou only a few feet above the normal water level of the stream. In case of a heavy rain or rise in the bayou, a common occurrence in this area, the polluted water runs into the bottom of the well where it moves laterally through the stratum and is probably pumped out again in some nearby well. The question then arises, can underground water strata become contaminated? In answer to this, the writers would say, generally no, but locally, emphatically yes.

CASING FAILURES

Casing failures in this locality are rather numerous and may be attributed to many causes, mainly: electrolysis, corrosion due to inactivity of the well, corrosion due to soil conditions, faulty mechanical working parts in the pumping equipment, defective seals and inferior casing material. The average life of casings in this area is approximately 10 years. Casing failures are recorded in the Houston area as occurring after from 5 to 22 years of service with a majority happening after approximately 9 to 10 years. From data accumulated, definite causes of these failures have been determined in approximately 25 cases. Among the 116 known abandoned wells, their abandonment in most cases may be attributed to faulty casing and screen conditions. Where electrolysis has been the cause of failure, there has been absolutely no warning that would indicate the impending dangers, but instead, the complete collapse occurs immediately. In one instance in particular, the pit casing collapsed above the pump dumping debris into the well and "freezing" the pump so tightly it could not be pulled. In another occurrence of this type of failure, a section of the distribution system was filled with muddy water and sand before the failure was located and the pump stopped. This caused the citizens, as well as the Department, much inconvenience and worry.

Where casing failures have been found due to the inactivity of the well, most of them have been due to open tops that have allowed surface and rain water to trickle down the inside of the casing and air line. One instance in particular is a well in a railroad yard surrounded by cinders and oil waste, a condition that is highly corrosive in itself.

Corrosive soil is rather prevalent in and around Houston, due to the flatness of the ground and its low elevation. There is also a quicksand stratum, approximately 10 feet under the surface which has proven highly corrosive in quite a few instances. These corrosive soils can be definitely traced to about 500 feet below the surface. In several instances, the casing was found to be pitted and in a very bad condition from 15 to 100 feet below the surface and, after careful examination, the soil was found to be highly acid. In another, the casing in the well was pitted and leaking at 500 feet below the surface. This casing looked as if it had been perforated by a perforating machine.

Another example of this type of failure was found in a railroad freight yard where a supply well became too salty for boiler use and upon investigation it was found that a large hole had been eaten in the casing at the same elevation as the water in a nearby bayou (stream). The salt content of the bayou water at this point has reached as high as 700 p.p.m., depending on the tide. Many wells have had to be abandoned in the vicinity of Houston's port due to high salt content of the waters in the Houston Ship Channel. This Channel water entered the surface sand strata, saturating them and attacking the casings in practically every well in this locality. The possibilities of this can be realized when it is taken into consideration that the Channel is noticably affected by tide and that its salt content reaches as high as 3000 parts per million.

Attention was called to a well, along the ship channel near the turning basin, in which the water level in the well was rising instead of falling. The latter is characteristic of wells in this area due to mechanical and chemical clogging of the screen openings. This condition excited curiosity more than any other because of the age of the well. It had been drilled between 1890 and 1900 and had never been reworked. Upon investigation, it was found that the water level in the well was approximately 10 feet above the normal water level throughout the entire area and the elevation of the water in this well was approximately the same as the water level in the ship channel which is about one hundred feet away. After lowering the water in the well, it was discovered that the casing had been entirely eaten away for a distance of approximately 10 feet and that the channel water was literally pouring into the well. The salt content of the channel at this point averaged about 1000 parts per million.

At one of the city's leading industrial plants, a well was drilled in the foundry yard at a convenient point for water distribution without taking into consideration sanitary or other damaging conditions. During the process of drilling, many feet of cinders were found near the surface. These cinders, after several years, proved to be the cause of the several failures in the well's casing, due to the well known and much discussed corrosive qualities of cinders. Other examples where soil corrosion has been the cause of casing failures in this area are the case of a cement company's well which went bad at approximately 500 feet below the surface, the instance where tide affects the water level in the wells at one of our large refineries, and many other such cases, histories of which would confirm the above mentioned facts.

Casing failures due to mechanical working parts are forcefully shown in the case of a well in one of our downtown buildings, where a 2-inch air line was inserted in a 4-inch well. At the start of pumping the air line whipped against the inside of the casing and after many years of such whipping finally wore a series of holes the entire length of the casing.

Leaks in well casings are commonly caused by broken or poorly constructed seals between casings of different sizes. An example of this condition is shown in the case of an old City well that started pumping turbid water and could not be cleared after many weeks of vigorous pumping and thorough examination of both casing and screen. The real trouble was not discovered until an impression block was run into the well and revealed the deterioration of or the bad construction of the concrete seal between the 24-inch pit and the 12-inch casing. Any number of cases could be cited where a lead seal has been applied and only sealed on one side.

Inferior casing has been the cause of any number of well failures in this area, especially in wells that were drilled during and right after the war period from 1915 to 1922. Evidently, only poor materials were available at that time for use in the manufacture of casing. A number of instances, especially in the case of oil wells, have come to the attention of the writers where entire strings of casing have completely collapsed due to inferior strength. Oil and water wells are drilled and constructed in much the same method in this section. It is evident that casing failures are a decided hazard in this area and should be a most important subject for study from the standpoint of health where wells constitute the domestic water supply.

RURAL AND SUBURBAN WELLS

In the outlying areas, the well supplies are subjected to unfavorable sanitary conditions in the form of cess pools, septic tanks, privies, etc., whereas in the more thickly settled areas, the greatest hazard is the proximity of well supplies to sanitary sewers. In 1930, 80 percent of the population was served by sanitary sewers. The remaining 20 percent serviced as follows: Privies, 42,870; septic tanks, 13,720; to bayou, 715. The sewer system consisted, on December 31, 1931, of 532 miles of brick, meriwither, reinforced concrete, vitrified clay, concrete pipe and cast iron pipe, the latter being less than 5 miles of the total. It is not only impractical, but almost impossible to construct water tight sanitary sewers. In this section, due to only slight differences in elevation in the entire city, sewer lines frequently overflow

through manholes during heavy rains. In this manner, storm sewers, at times, carry an enormous amount of pollution. It can readily be seen that wells located in streets and sidewalks are subject to contamination from sewers particularly when streets are flooded. All wells in the downtown area are within a short distance of sanitary sewers and the wells in the less thickly built-up sections are menaced by either septic tank effluents or shallow wells drilled to dispose of such effluents. It is believed that no wells should be located nearer than 150 feet of any sewer and then only in areas where control can be maintained over all other governing factors such as drainage, trespassing, etc.

HOUSTON RESERVOIRS

The City of Houston has 8 reservoirs and settling tanks ranging in capacity from 30,000 to 15,000,000 gallons, all of which are constructed of reinforced concrete and covered with a reinforced concrete slab. These reservoirs are for the most part above ground with several partially sunk below the ground level and one completely underground. The reservoirs that would have the greatest bearing on sanitation would be the larger four, namely; the 300,000 at Scott Street and 700,000 gallon at Heights, the 4,000,000 at Central and the 15,000,000 gallon at Sabine Street. They are of modern design and construction and are rectangular in shape. The inlets and outlets of these reservoirs are in every instance designed to afford the best circulation possible for the water during its retention. Even with this type of design the retention of the well water, under its normal temperature of 80 degrees, is long enough to incubate undesirable organisms. The sanitary conditions surrounding these reservoirs are considered very good; the ventilators are all screened; the manholes are covered with lids free from holes and locked; the reservoir area is fenced with a 7-foot non-climable fence and the gates are kept locked to prevent trespassing.

Samples are collected by the regular sample collector from all reservoirs in use six days each week. The results of 5354 examinations from reservoirs are shown in table 2. Of the 242 reservoir-months tabulated, 88 reservoir-months or 36.36 percent of the total had an index in excess of that permitted by the drinking water standards. The wells as individual units frequently showed excessively high indices, but when this water is kept in storage, even for short periods of time and in relatively small quantities, there is a noticeable in-

TABLE 2

Percent of 10 cc. portions confirming positive for Coli-aerogenes group in reservoirs (raw water) and in plant taps (chlorinated water)

YEAR	MONTH	CENTRAL PLANT			SOUTH END		SCOTT ST.		HEIGHTS		MAGNOLIA PARK		WEST END		NORTH SIDE		PARK-PLACE		EAST END	
		4 M. Res.	15 M. Res.	Tap	Res.	Tap	Res.	Tap	Res.	Tap	Res.	Tap	Res.	Tap	Res.	Tap	Res.	Tap	Raw	Tap
1929	October	24.3	11.8	1.7	0.87	6.9	6.9	0.0	8.7	0.87	3.5	0.87	2.6	0.87	2.7	0.0	63.3	9.1		
	November	13.0	20.9	6.9	0.87	1.7	24.3	0.87	8.7	0.0	14.8	1.8	9.5	0.0	6.9	0.0	42.6	6.9		
	December	2.4	10.8	0.8	2.4	4.8	19.1	0.8	20.0	0.0	13.3	1.6	2.5	1.6	2.6	0.0	22.5	12.0		
	Average	13.23	14.5	3.13	1.38	4.43	16.73	0.56	12.47	0.29	10.53	1.42	4.87	0.82	4.07	0.0	42.8	9.33		
1930	January	0.87	0.22	0.0	0.8	0.0	38.4	0.0	0.0	0.8	15.2	0.0	3 2	0.8	9.6	0.0	12.0	0 8		
	February	20.0	9.5	0.0	0.0	0.0	42.8	0.96	0.0	0.0	35.2	0.0	1.9	0.0	0.9	0.0	19.0	4.7		
	March	41.6	29.1	1.6	8.3	0.0	12.1	0.0	8.3	0.0	42.5	0.0	2.6	0.0	5.0	4.0	24.1	0.8		
	April	10.0	32.1	4.2	4.1	0.9	55.0	0.0	0.83	0.0	66.6	0.0	0.0	0.0	0.0	0.0	48.3	6.6		
	May	4.8	8.3	0.0	3.2	0.0	35.2	0.8	10.4	0.0	36.8	0.0	4.8	0.0	8.8	0.0	1.6	0.0		
	June	33.3	9.1	3.3	2.5	2.5	50.0	0.0	20.8	1.7	15.8	0.0	2.5	0.8	1.6	1.6	2.5	5.0		
	July	23.8	21.9	0.0	3.8	0.96	26.6	1.9	8.3	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.96	0.0		
	August	3.2	7.5	0.0	13.9	0.0	27.2	0.0		0.0	0.8	1.6	2.4	0.0	11.2	0.8	0.0	0.0		
	September	6.4	7.2	0.0	8.8	0.0	22.4	4.0		1.6	8.0	0.0	1.6	0.0	8.2	0.8	0.0	1.6		
	October	7.8	7.0	6.0	6.0	0.8	37.4	6.0	11.1	0.0	5.2	2.6	6.0	2.6	25.2	5.2	0.0	0.0		
	November	0.0	8.1	0.0	0.9	0.0	36.3	0.0	1.8	0.0	4.5	0.0	5.1	0.0	16.3	1.8	0.0	9.5		0.0
	December	0.8	2.7	0.0	2.5	0.0	34.4	0.0	4.8	0.0	4.0	0.0	10.8	0.0	39.2	21.6				0.0
	Average	12.71	11.89	1.25	4.56	0.43	34.81	1.13	6.63	0.34	19.55	0.35	3.40	0.35	10.89	2.98	9.86	2.63		0.0
1931	January	0.0	3.0	0.0	0.0	0.7	12.3	0.0	0.7	3.0	3.0	0.0	0.0	0.0	17.7	0.0			1.0	0.0
	February	2.8	0.0	0.0	1.9	0.0	10.4	0.9	0.0	0.0	1.0	0.0	0.9	0.0	1.9	0.0			0.0	0.0
	March	11.3	5.4	0.8	4.5	0.0	11.3	0.8	0.0	0.0	1.7	5.2	0.0	0.0	4.7	0.0			0.0	0.0
	April	7.2	35.2	4.0	0.8	0.0	28.0	0.0	0.0	0.0	0.0	0.0	12.0	0.8	6.4	0.0			0.0	0.0
	May	4.1	23.3	0.0	0.0	0.8	50.8	0.0	0.8	1.6	0.0	0.8	14.4	0.8	0.8	0.0			0.8	0.0
	June	10.4	5.6	0.8	0.0	0.0	32.0	0.0	16.0	6.4	0.8	0.0	15.0	4.8	7.2	0.0			1.0	0.8
	July	20.8	5.8	4.1	3.3	3.3	23.3	0.0	10.0	7.5	1.6	0.0	10.0	0.0	22.5	0.8			0.0	0.0
	August	4.6	11.5	4.6	10.0	0.0	10.7	3.0	2.3	0.7	10.0	3.0	0.0	0.0	23.0	0.0			5.0	0.0
	September	8.3	1.6	0.0	49.1	2.5	19.1	0.0	0.8	4.1	4.1	0.0	10.8	0.0	15.8	0.8			4.1	0.0
	October	8.3	5.0	0.0	4.1	0.0	26.6	0.0	0.0	0.8	0.0	4.1	0.0	0.0	11.7	1.7			0.8	1.6
	November	17.4	6.0	1.7	2.6	0.0	26.9	0.0	0.0	3.4	0.8	0.0	5.2	0.0	10.4	0.0			1.7	1.0
	December	15.8	5.0	0.0	2.5	0.0	60.0	0.8	0.0	0.0	9.1	0.0	14.1	0.0	2.5	0.0			0.0	0.0
	Average	9.25	8.95	1.33	6.56	0.6	25.94	0.45	2.55	2.29	2.67	1.09	6.86	0.53	10.38	0.27			1.20	0.28

crease in the indices, averaging approximately four times that of the wells.

CHLORINATION OF WELL WATERS

During the same period that samples were collected and examined from the wells and reservoirs, samples were also collected, examined and the results tabulated from plant taps. These data are introduced here to bring out the significance of treating well water by chlorination. In comparing the results tabulated on plant taps after chlorination, the following is brought out: The B. coli index of the water from the wells and reservoirs has often exceeded the allowable as permitted by the standards of drinking water, while the treated tap water has always been well within the allowable. This is more clearly brought out in comparing the water from Scott Street Plant Reservoir and Scott Street Plant Tap after chlorination for the year 1930. The average index for the raw water from the reservoir was 38.81 percent, while the same water, after chlorination, had an index of only 1.13 percent.

In the opinion of the writers, the foregoing data conclusively demonstrate the efficiency of chlorination as applied to the treatment of well water and that this type of supply can become heavily polluted and should be controlled at all times.

The data show that wells in this area are subject to contamination at all times and that proper supervision and care should be exercised by well owners to provide safe water for all purposes. The following statements by Ferguson and Klassen[1] express the situation clearly. "The fact that a well supply has been used for many years and has not yet caused any water-borne illness is not proof that the supply is not subject to contamination. Nearly all of our water-borne epidemics have been caused by supplies that were locally thought to be safe, but which were subject to contamination. It is only a question of time before a dangerous type of contamination occurs and causes illness among the consumers, but it is reasonable to assume that where and when avenues for any kind of contamination are open, dangerous contamination may occur at any time under certain conditions."

CONCLUSIONS PRESENTED

From all the data in this article and after a great deal of study of the prevailing well conditions in this area, the writers have come to the following conclusions:

[1] Journal, January, 1929, page 1.

1. The shed area is satisfactory and pollution from this source is remote, as the area is well timbered, sparsely settled and free from fault formations.

2. The city wells, despite strict supervision during drilling and operation, are subject to high contamination at all times. No method has yet been found to sterilize the mud used in drilling nor has any new or old well ever been effectively sterilized even when a solution of 100 p.p.m. of free chlorine has been used.

3. Private well supplies are even more subject to contamination than city wells, because of their lack of supervision during drilling and operation and due to their location in relation to sanitary hazards.

4. The possible sources of pollution are definitely brought out by the conditions of abandoned wells, casing failures, location of sanitary sewers, cess pools, privies, etc. Rainfall and temperature factors have no great significance in the tabulated results.

5. Reservoirs, settling tanks and all other types of storage basins, whether city owned or private, due to the retention of the water in them are a grave problem and present a sanitary hazard at all times.

6. The results tabulated on plant taps after chlorination prove beyond a doubt, that this method is efficient, economical and very effective.

In closing this article, the writers emphasize the statement that in their opinion all wells in the Houston area without exception, should be treated and closely supervised before being used as public or semi-public supplies.

We take this opportunity to express our appreciation to Mr. Penn P. Livingston of the United States Geological Survey, The Layne-Texas Company, The Southern Engine & Pump Company and various owners of private wells in this area for their valuable assistance and coöperation in preparing this article.

THE LIVINGSTON, MONTANA, MUNICIPAL WATER WORKS

By J. R. Cortese

(Superintendent, Water Department, Livingston, Mont.)

In 1911, the franchise held by the private company furnishing Livingston with water expired. It was the opinion of the then city officials that the existing conditions were not sufficient, or modern enough to take care of the demand, and with that in mind, inaugurated the idea of a municipal owned and operated plant. The privately owned company derived their source of supply from the Yellowstone River, where much of the surface drainage from the city entered into the river above the intake. The water flowed into wells, was then chlorinated, without being filtered, and then pumped into the distribution mains, the overflow going into a reservoir having a capacity of 175,000 gallons. During the spring months of the year the Yellowstone is very heavy with sediment and naturally polluted. The State Board of Health, after conducting sanitary surveys, had recommended filtration with chlorination. All efforts to bring this about were defeated by the serving company. Thus in 1911 the city officials approached the company with the idea of improving conditions, the purchase of their plant by the city, or the construction of a new plant by the city. The company refused to negotiate. Consequently an appraisal was made by competent engineers of the existing plant. This appraisal showed that the property was worth \$165,662.00. They also made an estimate of \$225,000.00 to build a new plant, modern in every respect, and as recommended by the State Board of Health. But acting on advice from the engineers, and rather than enter into competition with the existing company, the city officials renewed efforts to purchase the private plant, to the extent of offering more for the plant than it would cost to build a modern plant. The city, however, did not meet with success.

After two years of negotiations the city voted \$260,000.00 in bonds for the construction of a new plant and distribution system. The plant was located on the Yellowstone River, but at a point above the city in order to get away from the city's surface drainage. Although

the preliminary steps were taken in 1911, it was approximately eight years later, before the city put its plant in operation. Injunction after injunction was brought against the city, first against the bond election, then the sale of bonds, then against the letting of contracts. In fact no form of known litigation was left unused in preventing the city from carrying out its plans. All of this cost the city considerable expense and much wasted time.

On January 1, 1919, the Livingston municipal water works sold its first water. Although the city had been through a fight prior to the opening of the plant to operation, the real fight came in getting patrons. Competition was keen and much of the time bitter. With a capital outlay of $260,000.00 for their plant the city gradually lost money until 1922, when it was forced to borrow $20,000.00 to continue operation, making a total debt against the plant in 1922 of $280,000.00. The privately owned plant continued operation until 1926. Up to that time it had made no improvements in its plant. All this brought about the ultimate success of the city's plant. In 1926 the city purchased the private system for $8,000.00.

It is not my intention in presenting this early history to offer inducement or encouragement to other cities to build and operate competing plants. This course was advised against in Livingston, and every effort was made by the city to avoid it, but the city was forced to bring about better conditions for the sake of sanitation and fire protection. It is doubtful, had the existing conditions been safe, whether municipal ownership would have ever been undertaken, much less thought of.

It is interesting to note the following figures. With a capital outlay of $280,000.00 invested in 1922, the city plant on June 30, 1931 showed $359,468.89 capital invested, with an outstanding indebtedness of $20,000.00 in bonds. These bonds are serial and not due until January 1, 1933. On January 1, 1932, the water works had a cash balance in the amount of $27,828.70. The operation and depreciation costs of pumping and delivering water to the consumer have been as follows:

year	*dollars per million gallons*
1927	38.25
1928	40.40
1929	38.00
1930	39.46
1931	46.60

The source of supply for the municipal plant is the Yellowstone River, draining a water shed of over 5000 square miles to the south of Livingston. The source is considered sufficient and practically inexhaustible. The intake to the plant is of cast iron pipe and consists of one 14-inch, one 16-inch and one 24-inch pipe extending into the river channel and about two feet under the gravel bed of the stream. These pipes convey the water by gravity approximately 200 feet to the preliminary settling basin or wells. From there it is pumped by low duty pumping units to the filter beds.

PUMPING STATION

The plant is located on the bank of the Yellowstone about one mile southwest of the business district of the city. The construction is of concrete and brick throughout, one story high and with full basement. The pumping plant and units and filter beds are housed in this plant. The plant consists of two 1.5 m.g.d. low duty, Hill, single stage turbine pumps, driven by two 10 horsepower, 28 ampere, 60 cycle, 220 volt, General Electric induction motors. The pumps can be operated either singly or in duplicate.

One 2 m.g.d. low duty Worthington, single stage, turbine pump in direct connection to a 30 horsepower, 2200 volt, three phase, induction motor. This pump is independent of the other units and can be operated in conjunction with them or singly.

Two 1.5 m.g.d. each, high duty, two stage turbine pumps, directly connected to two 100 horsepower, 2200 volts, 23 ampere, 60 cycle, three phase, G. E. motors.

One 2 m.g.d. high duty, two stage turbine pump directly connected to one 100 horsepower, 2200 volt, 23 ampere, 60 cycle, three phase G. E. motor.

All these pumps can be operated either singly or in duplicate, against a 230 foot head.

The pumps take suction through 14- and 16-inch cast iron pipe lines from the clear water well, where the water is chlorinated, and discharged into a 24-inch class D cast iron header, connected to a 24-inch Venturi meter, branching from there into two 14-inch cast iron mains to the distribution system. These two mains can be operated independently or in unison, being equipped with gate valves to regulate the flow.

FILTRATION PLANT

Low duty pumps discharge into concrete mixing chambers from which water flows into the coagulation basins, of 350,000 gallons capacity each. These basins are constructed of concrete, covered, and are 30 by 100 feet by 15 feet deep. From the coagulation basins the water passes to the sand filters. Four rapid sand filters handle 750,000 gallons each per day. From the filter beds the water passes to the clear water well which has a capacity of 50,000 gallons. From here the high duty pumps take suction and discharge the water into the distribution mains, heretofore described.

The net-work of transmission mains in the built up sections of the city consists of parallel 4-, 6- and 8-inch mains with 8- and 12-inch cross feeders at intervals of 1600 feet. All mains are of cast iron, and in excellent condition, having been installed in 1918. The mains are placed at an average depth of 5.5 feet, and are class B pipe of the American Water Works Associations specifications, with bell and spigot joints. We have approximately 18 miles of transmission mains, ranging from 4 to 14 inches, in the city and 160 fire hydrants on the system, all being double standard. These hydrants are of the post type with 6-inch or larger barrels, and self draining. The hydrants are inspected in the spring and fall. We have a total of 108 valves in the system, varying in sizes from 4- to 14-inch.

RESERVOIR

The reservoir is located to the north of the city about three-quarters of a mile, with an elevation of 230 feet. It is constructed of reinforced concrete, cylindrical in shape, 115 feet in diameter and 14 feet deep, with a capacity of 1,000,000 gallons. The reservoir is covered with a concrete slab roof and supported by sixty-six 10- by 10-inch concrete columns. It is equipped with a by-pass and check valve for releasing the flow of water when the pressure in the system drops. Height of water is indicated by a gauge in the pumping plant.

The work preliminary to the movement inaugurated to the establishing of our plant and the actual engineering plans and inspection of the plant were carried out by Burns and McDonnell, Consulting Engineers of Kansas City, Missouri. The contract for the construction of the plant proper was completed by the Pittsburgh Filter Company. This included the filter beds, and at a cost of $78,500.00. The pumping machinery was furnished and installed by the Merkle

Machinery Company at a cost of $7,071.00. The trenching, hauling and installation of the distribution system by the McLaughlin & O'Neil Company at a cost of $28,483.57. Cast iron pipe was furnished by the American Cast Iron Company at a cost of $85,446.01, hydrants and valves, by the Merkle Machinery Company at a cost of $7,325.00, using Iowa hydrants.

(Presented before the Montana Section meeting, April 1, 1932.)

THE NEW ATLANTA TURBIDIMETER

By Paul Weir

Superintendent Filtration Water Works, Atlanta, Ga.

Turbidity is a measure of suspended matter which obstructs the passage of light through a medium. This may be due to silt, clay, suspended minerals, organic matter, microörganisms and the like. It is expressed in terms of the turbidity produced by a given weight of silica. The comparison of turbidities is considered from the viewpoint of a unit based upon appearance, rather than quantity. Equal weights of suspended matter do not necessarily constitute the same turbidities, as in the case of silt and sand, which produce a less turbidity than finely divided clay particles. Therefore, the ratio between silica turbidity determined optically, and suspended matter determined gravimetrically, is an important index of the character of suspended matter. This is borne out by the fact that the "Turbidity Coefficient" equals suspended matter divided by the silica turbidity. The colloidal material that we will refer to from time to time means matter that is so finely divided that it does not settle out rapidly.

The Standard Turbidity Unit in this discussion will refer to that used by the United States Geological Survey, namely: A water which contains one hundred milligrams of silica per liter in such a state of fineness that a bright platinum wire, one millimeter in diameter, can just be seen when the center of the wire is 100 millimeters below the surface of the water and the eye of the observer is 1.2 meters above the wire. The turbidity of such a water is arbitrarily fixed at 100 parts per million.

The Platinum Wire and Jackson Candle Turbidimeters give satisfactory results on most raw waters, but neither give entirely accurate results on applied and filtered waters since modern practice demands a water containing a minimum turbidity.

Well operated filters having delivered to them a properly coagulated and settled water should remove all of the readily visible turbidity from the applied water. Accepted practice recommends that

they should deliver consistently effluents containing less than 1 part per million of turbidity.

Accurate turbidity measurements on filtered water are of considerable aid in checking efficient operation. Where more than one filter is in service, a faulty combined effluent may be due to the discharge

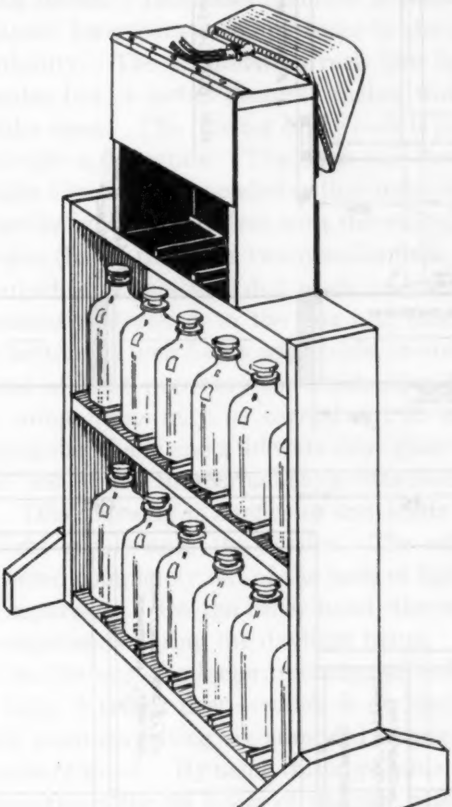

FIG. 1. ATLANTA TURBIDIMETER

of one particular filter. In this event, the suspected filter may be taken out of service and the difficulty rectified before more serious trouble occurs.

Dilutions with distilled water are made up from the Standard Turbidity Unit ranging from 25 to 0 parts per million, using 500 cubic centimeter glass stoppered, clear glass Pyrex bottles. It is essential

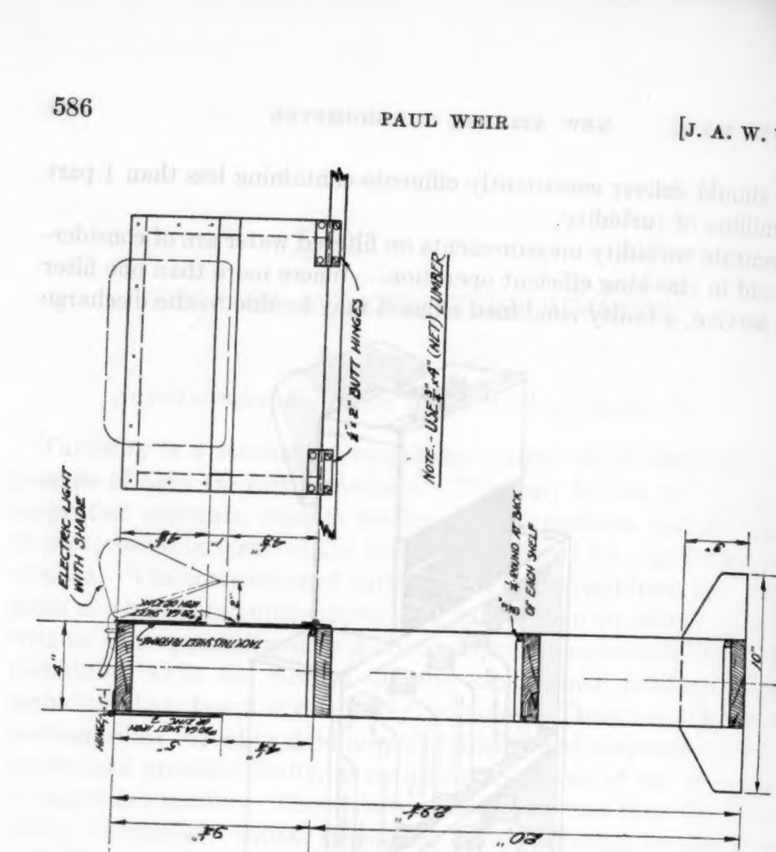

FIG. 2. ATLANTA TURBIDIMETER WITHOUT STANDARDS

that the dilutions for these standards be prepared with the greatest of care. The Atlanta method of testing with these standards (see figure 1) consists of placing the sample to be tested in a bottle similar to those of the standards. This bottle is placed between two of the standard suspension bottles, which closely approximate the turbidity of the water being tested. This determination is carried out on a rack suitably adapted for accurate comparisons to the nearest part per million of turbidity. The examination rack (see figure 2) consists of a rectangular box, 4 inches deep, 11 inches wide, 8½ inches high, with both sides open. The interior of the rack is painted a dull black and the exterior a flat white. The open side toward the observer has a metallic 5 inch flap suspended so that reflections from the shoulder of the bottles will not interfere with the examination. On the reverse open side (back) there are two metallic flaps, both highly polished on the outside and painted a dull black on the inside. The top flap is permanently attached to the box and extends down 4 inches, while the bottom 4½ inch flap is adjustable, in order to permit the proper amount of light necessary for conducting the test. In order that these comparisons may be carried out at night, a desk lamp, with a rectangular shade and a 40 watt clear glass electric light bulb, is mounted just above the permanently attached flap on the back of the box. This flap acts as a reflector and tends to distribute the rays of the light evenly onto the bottles. The adjustable flap on the back is lowered completely out of the path of light and is not used for night comparisons. On the other hand, the artificial light is not used for comparisons during the daylight hours. This testing rack is mounted on the top of a larger, rectangular rack—22 inches wide, 18 inches high, 4 inches deep—which is divided into two 9 inch shelves, each accommodating six standard suspension bottles. Both racks are made of wood. By using this apparatus, comparisons may be made throughout the 24 hours of the day with exceedingly accurate results.

PREPARATION OF STANDARDS

There are two different procedures used in the preparation of Standard Turbidity Suspensions at Atlanta. One method consists of using Fuller's earth with distilled water and the other method consists of using raw river water.

The Atlanta Turbidimeter used the following Standards: 25, 20, 15, 10, 5, 4, 3, 2, 1, 0.5, 0.2 and 0.0. We have found that most satis-

factory results are obtained by using the raw river water for the Standards ranging from 25 to 5 parts per million and Fuller's earth for the Standards ranging from 4 to 0 parts per million.

Raw river water method

A stock solution having a turbidity of 100 parts per million is determined from the raw river water by the Jackson Candle Turbidimeter (table 1).

TABLE 1

TURBIDITY STANDARDS	VOLUME OF STOCK SOLUTION REQUIRED	VOLUME OF DISTILLED WATER TO MAKE UP 500 cc.
p.p.m.	*cc.*	
25	125	375
20	100	400
15	75	425
10	50	450
5	25	475

Fuller's earth method

About five grams of Fuller's Earth are added to about one liter of distilled water. This is thoroughly agitated several times during the day and then permitted to stand about 24 hours. The supernatant liquid is withdrawn without disturbing the sediment on the bottom and the turbidity tested with the Jackson Candle Turbidimeter and adjusted until it is exactly 25 parts per million. This constitutes a stock solution (table 2).

TABLE 2

TURBIDITY STANDARDS	VOLUME OF STOCK SOLUTION REQUIRED	VOLUME OF DISTILLED WATER TO MAKE UP 500 cc.
p.p.m.	*cc.*	
4	80	420
3	60	440
2	40	460
1	20	480
0.9	18	482
0.7	14	486
0.5	10	490
0.3	6	494
0.1	2	498
0.0		500

All dilutions should be made with zero turbidity distilled water. This may be had by redistilling distilled water. Standard Turbidity Suspensions should be prepared new from the stock solution every two or three weeks, if accurate results are to be obtained.

A careful study of turbidities will lead to the development of interesting and fundamental data which may be of vital importance in coagulation and bacterial reduction. The most important single interpretation of turbidity measurement is that it is a reliable index indicating the amount of coagulant necessary to properly clarify a water.

Several plants have worked out a chart showing the chemical-turbidity ratio, computed directly from the daily turbidity record of the water and the amount of chemicals used in its purification. A marked improvement in operation and a substantial chemical reduction has been brought about by this procedure in several instances. However, this relationship must be worked out for each individual plant using it.

Where large quantities of chlorine are used in sterilizing filtered water to make it safe for consumption, disagreeable tastes and odors are often present. A careful study, with the proper turbidity equipment, will oftentimes reveal that these difficulties may be greatly reduced if the proper low turbidities are maintained in the filtered water. Fine turbidity is frequently the means by which bacteria pass through the filter bed. Bacteria, however, are not removed in direct proportion to turbidity; but, nevertheless, there does exist a definite relationship between the two.

It is, therefore, obvious that a comprehensive study of turbidities will lead to the use of specific treatment methods for certain water conditions, thereby giving better operation, greater control and a much improved product.

(Presented before the Southeastern Section meeting, March 23, 1932.)

ABSTRACTS OF WATER WORKS LITERATURE[1]

Frank Hannan

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Purifying Waters. Georg Ornstein. Fr. 684,642, November 8, 1929. From Chem. Abst., **24:** 5403, November 10, 1930. Algae and other living organisms in water are destroyed by simultaneous action of chlorine and copper on water.—*R. E. Thompson.*

Report on (the Determination of) Radioactivity in Drugs and Water. J. W. Sale. J. Assoc. Official Agr. Chem., **13:** 308–10, 1930; cf. C. A., **22:** 3957. From Chem. Abst., **24:** 5428, November 10, 1930. Determination of radioactivity in sample of water by United States Bureau of Chemistry method (Sale, C. A., **19:** 3145) by outside collaborator gave satisfactory results, but further collaborative work is considered essential.—*R. E. Thompson.*

Determination of the Hydrogen-Ion Concentration as an Aid in the Study of Cement and Concrete. Karl Biehl. Zement, **19:** 269–73, 1930. From Chem. Abst., **24:** 5453, November 10, 1930. Colorimetric pH values of 1:100 cement-water suspensions for various types of cement average about 10.5. Resistance of concrete to water is considered from standpoint of the pH value of various natural waters and prepared salt solutions.—*R. E. Thompson.*

Apparatus for Testing the Water-Impermeability of Concrete. Hans Hecht. Zement, **19:** 472–3, 1930. From Chem. Abst., **24:** 5454, November 10, 1930. The water pressure is kept constant or varied at will by changing air pressure on supply tank. Twelve pieces up to 30 inches in diameter can be tested simultaneously with pressures of from 0 to 20 pounds per square inch.—*R. E. Thompson.*

Elimination of Phenols from Effluents of Coking Plants. W. Fitz. Asphalt u. Teer, **30:** 552–3, 1930. From Chem. Abst., **24:** 5466, November 10, 1930. Liquors of low phenol content are made harmless by aëration in catch basins. More economically, phenols are extracted from ammonia liquors with benzene and isolated by fractionation, or treatment with sodium hydroxide. In third

[1] Vacancies on the abstracting staff occur from time to time. Members desirous of cooperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

method, liquor is freed from tar in filter bed of iron filings, then passed over activated carbon, which absorbs phenols up to from 5 to 10 percent of its weight. Absorption beds are regenerated with benzene flowing in countercurrent direction. Two units alternate in operation.—*R. E. Thompson.*

The Chemical Variations in Mill Water, and Their Relation to the Use of Sulfuric Acid in Sizing. A. B. HALWARD. Tech. Chem. Papier Zellstoff-Fabr., **26**: 165–8, 1929. From Chem. Abst., **24**: 5493, November 10, 1930. Bad effects of hard water in sizing can be largely eliminated if sufficient sulfuric acid is added, before sizing, to render water neutral to methyl orange.—*R. E. Thompson.*

Superheaters for High Steam Temperatures. MÜNZINGER. Feuerungstech., **18**: 145, 1930. From Chem. Abst., **24**: 5539, November 20, 1930. Failure of superheater delivering steam at 480° led to investigation, which showed that at from 500° to 600°, ordinary open-hearth steel is attacked by steam, giving Fe_3O_4.—*R. E. Thompson.*

The Velocity of Solution of Oxygen in Water. II. SUSUMU MIYAMOTO, TETSUO KAYA and AKIRA NAKATA. Bull. Chem. Soc., Japan, **5**: 229–40, 1930; cf. C. A., **24**: 3699. From Chem. Abst., **24**: 5575, November 20, 1930. Solution velocity was studied by means of rate of oxidation of sodium sulfite solution, previously found to be independent of concentration of sodium sulfite. Mixtures of air and oxygen were bubbled at 2 different rates through the solution at 20°. Rate of solution varied as linear function of oxygen partial pressure.—*R. E. Thompson.*

The Ionization Constant of Water at 25° from the Electromotive Force of Cells Without Liquid Junction. ELLIOTT J. ROBERTS. J. Am. Chem. Soc. **52**: 3877–81, 1930. From Chem. Abst., **24**: 5577, November 20, 1930. Ionization constant, determined by new method, is $(0.988 \pm 0.004) \times 10^{-14}$ at 25°.—*R. E. Thompson.*

Methods for Measuring Voids in Porous Material. J. D. SULLIVAN, G. L. OLDRIGHT and W. E. KECK. Bur. Mines, Rept. of Investigations 3047, 8 pp., 1930. From Chem. Abst., **24**: 5595, November 20, 1930.—*R. E. Thompson.*

The Radium Content of Petroleum-Bearing Waters from Baku and from Daghestan. B. NIKITIN and L. KOMLEFF. Compt. rend., **191**: 325–6, 1930. From Chem. Abst., **24**: 5617, November 20, 1930, Seventy-two samples from Baku were examined. One group from Bibi-Eibat contained 3×10^{-11} percent radium. Water from one well contained 1.6×10^{-10} per cent radium. Richest group was from layer at 600-meter depth. Twenty-two samples from Daghestan were examined. Usual content was 1.2×10^{-10} percent radium and 0.03 percent barium; there was no relation between the radium and barium contents.—*R. E. Thompson.*

The Presence of Uranium in Mineral Waters. The Ratio of This Element to Radium. HERCULANO DE CARVALHO. Compt. rend., **191**: 95–7, 1930.

From Chem. Abst., 24: 5617, November 20, 1930. Uranium was found always to accompany radium in natural waters from Portugal, but ratio was not constant.—*R. E. Thompson.*

The Radioactivity of the Springs and Minerals of the Sludjanka District. S. A. Arzibishev and I. A. Parfianovich. Compt. rend. acad. sci. U. S. S. R., Ser. A. 1928: 125–7; Chem. Zentr., 1930: I, 810. From Chem. Abst., 24: 5618, November 20, 1930. Springs examined had radioactivity corresponding to from 0.3 to 1.12 Mache units.—*R. E. Thompson.*

Test Papers for Detecting Magnesium. Irwin Stone. Science, 72: 322, 1930. From Chem. Abst., 24: 5665, November 20, 1930. Dip filter paper in 0.01 per cent alcoholic solution of *p*-nitrosobenzeneazoresorcinol, dry, and cut into 4-inch squares. Preserve in amber bottle. To make test, place drop of test solution on the paper, dry, and immerse in 1 percent sodium hydroxide. Magnesium gives blue spot in reddish field. If original solution contains much acid, the color is yellow at first. As little as 0.005 milligram of magnesium will give the test.—*R. E. Thomspon.*

Notes on the Determination of Ammonia in Water. Marie W. E. Evers. Chem. Weekblad, 27: 475–80, 1930. From Chem. Abst., 24: 5667, November 20, 1930. If water contains less than 46 p.p.m. bicarbonate ion, it is necessary, in order to distil off quantitatively all ammonia present, to add sodium carbonate, magnesia, or calcium carbonate. If more bicarbonate is present, no addition is required, irrespective of calcium and magnesium contents. Of the three salts mentioned calcium carbonate is recommended, as it is also formed during distillation of water containing sufficient bicarbonate.—*R. E. Thompson.*

Titrimetric Determination of Sulfates. M. Dominikiewicz. Bull. trav. dépt. chim. inst. hyg. état (Poland), 31: 1, 3–6 (German 6); Przemysl Chem., 14: 241–5, 1930. From Chem. Abst., 24: 5669, November 20, 1930. Benzidine is used as indicator for titrimetric determination of sulfates in absence of compounds reacting with barium chloride, chromates or benzidine. To 100 cc. of solution, which has been acidified with hydrochloric acid and heated to boiling, add from 20 to 25 cc. 0.1 normal barium chloride solution. After boiling, neutralize with ammonia and titrate excess barium chloride with 0.1 normal ammonium potassium chromate until blue coloration appears on spotting on benzidine paper prepared from 0.5 gram benzidine, 25 cc. alcohol, and 5 cc. acetic acid. One cc. barium chloride is equivalent to 4 milligrams SO_3. Comparative determinations were made with this and the gravimetric method on solutions of known content of sulfuric acid and potassium sulfate in river water, artificial Carlsbad salt, urea, etc. Method was found very suitable for such investigations.—*R. E. Thompson.*

Calcareous Concretions in Streams Near Lexington, Virginia. Marcellus H. Stow. Am. J. Sci. (5), 20: 214–6, 1930. From Chem. Abst., 24: 5679, November 20, 1930. Small, rounded, calcareous concretions occur in beds of

all streams draining Ordovician limestone region around Lexington and Roanoke, Virginia. They have been formed by deposition of calcium carbonate from stream water on any nucleus present, such as pebbles, snails, twigs, mud, etc.—*R. E. Thompson.*

Chemical Composition and Mechanical Properties of Centrifugal Castings. J. E. HURST. Metallurgia, 2: 13–6, 54–6, 1930. From Chem. Abst., 24: 5692, November 20, 1930. Summary is given of chemical composition of centrifugally cast iron pipe made by various processes in different parts of world, together with résumé of work done by many investigators on mechanical strength of such pipe. Other physical properties considered in commercial evaluation of pipe and methods employed for their determination are described.—*R. E. Thompson.*

The Testing of Cast Iron. J. W. DONALDSON. Metallurgia, 2: 121–4, 1930. From Chem. Abst., 24: 5696, November 20, 1930. Methods are given of obtaining and of testing cast iron test bars for following physical properties: transverse strength, tensile strength, compressive strength, shear strength, fatigue resistance, impact resistance, wear resistance, and hardness.—*R. E. Thompson.*

Further Researches into the Evans Theory. E. MAASS and E. LIEBREICH. Korrosion Metallschutz, 6: 103–6, 1930. From Chem. Abst., 24: 5705, November 20, 1930. Further evidence is presented regarding validity of convection current explanation of presence of anodic and cathodic areas under liquid drops. Data seems to bear out MAASS theory rather than that of EVANS. —*R. E. Thompson.*

Further Information on the Evans Theory of Differential Aeration. E. HERZOG and G. CHAUDRON. Korrosion Metallschutz, 6: 171–2, 1930. From Chem. Abst., 24: 5705, November 20, 1930. Solution of 3 percent sodium chloride containing 1 percent hydrogen peroxide was introduced into drop of 3 percent sodium chloride solution which was resting on Armco iron plate. Central zone became cathodic; at edges iron salts were formed; at the boundary reddish precipitates were observed. Reversal of this phenomenon was obtained by changing concentration of hydrogen peroxide. Same phenomena were observed, but to lesser degree, with sea water. After a time cathodic area became covered with precipitate which was concluded to have been formed because of diffusion of ferrous iron from anodic zone since removal of drop showed no attacked areas at outer ring. If corroding medium has pH (as in case of magnesium chloride) sufficiently low, no precipitate will form and diffusion processes are possible.—*R. E. Thompson.*

Protection of Ferrous Metals by Metallic Coatings or by Chemical Means. J. BOURGAREL. Tech. moderne, 22: 529–34, 1930. From Chem. Abst., 24: 5705, November 20, 1930. Description of methods in use.—*R. E. Thompson.*

Regarding the Distribution of Corrosion Under Liquid Drops. U. R. EVANS. Korrosion Metallschutz, 6: 173–4, 1930. From Chem. Abst., 24: 5707, Novem-

ber 20, 1930. In answer to Dr. MAASS' criticism (C. A., 24: 3744) that no pictures were presented of corroded areas, author demonstrates by pictures attack of iron by liquid drops in air and in atmosphere of nitrogen. Author claims to have observed similar results under conditions in which no evaporation could take place, i.e., in absence of convection currents.—*R. E. Thompson.*

Protection of Metal Pipes from Outside Corrosion. A. ROCCA. Metallbörse, 20: 1829, 1930. From Chem. Abst., 24: 5707, November 20, 1930. Mixture of cement (alkaline and free from chloride) and asbestos offers good protection to metal pipes against external corrosion. Mixture is applied after thin layer of tar or bitumen.—*R. E. Thompson.*

Steel Mains and Corrosion. E. E. JEAVONS and H. T. PINNOCK. Gas J., 191: 203–4, 255–6, 1930. From Chem. Abst., 24: 5707, November 20, 1930. Steel mains properly bitumen-coated, laid and earthed according to authors' method, are subject to little or no electrolytic corrosion. Study was made of electrolytic corrosion in Mond high-pressure distribution system. Specifications are given for preventing electrolytic corrosion. Joints should be copper-bonded and at regular intervals wrought iron earth bars should be welded to mains.—*R. E. Thompson.*

The Local-Current Theory of Corrosion and Passivity. F. TÖDT. Z. physik. Chem., Abt. A. 148: 434–40, 1930; cf. C. A., 23: 5146. From Chem. Abst., 24: 5706, November 20, 1930. Corrosion in weakly acid, weakly alkaline, or neutral, solutions is dependent upon local currents whose size depends on the depolarization of oxygen at cathode. Significance of local action between metal and its oxide coating is discussed with regard to passivity and its periodic occurrence.—*R. E. Thompson.*

Recently Discovered Facts About Corrosion. F. N. SPELLER. Metal Progress, 18: 3, 48–53, 1930. From Chem. Abst., 24: 5706, November 20, 1930. A review.—*R. E. Thompson.*

Corrosion and Protective Coatings for Water and Superheater Tubes. ROBERT HOPFELT. Arch. Wärmewirt., 11: 243–6, 1930. From Chem. Abst., 24: 5706, November 20, 1930. Three examples of tube failure due to corrosion by hot oxygen, steam, silica, or sulfuric acid, are illustrated and discussed. Alumetizing will prevent such failures; it consists in spraying surface with molten aluminum in presence of flux. Material thus treated can be worked without destroying coating.—*R. E. Thompson.*

Critical Survey of the Methods of Removing Corrosion Products for Structures. PAUL NETTMANN. Korrosion Metallschutz, 6: 106–11, 1930. From Chem. Abst., 24: 5708. November 20, 1930. Methods of removing rust are discussed from economic viewpoint. Manual, mechanical, chemical, and blasting methods are considered from viewpoints of finish, ease of painting, and cost. It is concluded that no single method is entirely satisfactory.—*R. E. Thompson.*

Influence of Flux Coated or Covered on the Metal Arc Electrode. M. HARAMIISHI. J. Am. Welding Soc., 9: 33–46, 1930. From Chem. Abst., 24: 5708, November 20, 1930. Author describes series of experiments and gives micrographs from which he concludes that flux coatings enable introduction of metallic constituents into weld (other than those in core rod), facilitate control of welding temperature, and protect molten metals from contamination. —*R. E. Thompson.*

Electrode Research. M. HARAMIISHI. Welding J., 27: 174–7, 1930. From Chem. Abst., 24: 5708, November 20, 1930. Flux-coated and covered electrodes for metallic arc welding are considered.—*R. E. Thompson.*

The Welding of Metals with Special Reference to Flux-Coated Electrodes. E. D. LACY. Metallurgia, 1: 65–8, 1930. From Chem. Abst., 24: 5708, November 20, 1930.—*R. E. Thompson.*

Resistance-Welded Pipe. ERNEST E. THUM. Metal Progress, 18: 3, 33–7, 1930. From Chem. Abst., 24: 5708, November 20, 1930. A review.—*R. E. Thompson.*

Development of Code for Fusion-Welded Boiler Drums. C. W. OBERT. Metal Progress, 18: 3, 75–8, 1930. From Chem. Abst., 24: 5708, November 20, 1930. Proposed specifications for fusion welding of drums or shells of power boilers.—*R. E. Thompson.*

Welding. I. H. NAMACK and H. C. HOBART. Metal Progress, 18: 4, 71–3, 1930. From Chem. Abst., 24: 5708, November 20, 1930. A review.—*R. E. Thompson.*

Radium Concentration by Organisms. V. I. VERNADSKII and B. K. BRUNOVSKII. Compt. rend. acad. sci. U. S. S. R. Ser. A., 1929: 33–4; Chem. Zentr., 1930: I, 988. From Chem. Abst., 24: 5773, November 20, 1930. Various organisms living in water have ability to concentrate radium. This was noticed especially with the floating water plants *Lemna minor* (9.4×10^{-11} percent radium) and *Lemna polyrrhyza* (3.1×10^{-11} percent radium), which in maximum case contained 56.5 times more radium than surrounding water. It follows from the investigations that radium contained in water is concentrated in vegetable and animal organisms living in the water.—*R. E. Thompson.*

The Relation of pH Value of Medium to Selective Bacteriostatic Action of Dyes. JOHN W. CHURCHMAN. Proc. Soc. Exptl. Biol. Med., 27: 50–3, 1929. From Chem. Abst., 24: 5781, November 20, 1930. Divided agar plates, upper halves containing gentian violet 1 to 200,000 and pH varying from 5.2 to 12.7, were planted with various bacteria. Character of selective bacteriostatic activity of gentian violet was similar in all plates.—*R. E. Thompson.*

Determination of Boron in Natural Waters and Plant Materials. L. V. WILCOX. Ind. Eng. Chem., Anal. Ed., 2: 358–61, 1930. From Chem. Abst.,

24: 5253, November 10, 1930. Chapin method, which depends upon distilling off methyl borate, catching distillate in sodium hydroxide solution, and finally titrating boric acid in presence of mannitol, has been adapted to determination of boric acid in natural waters. Use of copper flasks and beakers is recommended, as lower blanks are obtained with such equipment than when glass is used.—*R. E. Thompson.*

The Preparation of Rivetless Mannesmann Wrought-Iron Pipes for Gas and Water Conduction and Their Resistance to Rusting. Wolfgang Ritter. Z. Österr. Ver. Gas-Wasserfach., 70: 121–8, 1930. From Chem. Abst., 24: 5272, November 10, 1930. Description of development of the industry. Mechanism of corrosion due to chemical oxidation, or solution, electrolysis, stray currents, and graphitizing is discussed.—*R. E. Thompson.*

Electrolytic Corrosion in Condensers. W. Schmid. Rev. gén. élec., 27: 685–90, 1930. From Chem. Abst., 24: 5277, November 10, 1930. General outline of theoretical principles.—*R. E. Thompson.*

Why Do Sodium Hypochlorite Preparations Differ in Corrosiveness G. N. Quam. Food Ind., 2: 366–7, 1930; cf. C. A., 23: 4277. From Chem. Abst., 24: 5277, November 10, 1930. Six commercial sodium hypochlorite preparations showed great variability in corrosive action. In general, Monel metal and Allegheny steel were attacked least, nickel being third and tin second, and copper was corroded most of all. Alkalies, added for stability, and other salts increase the corrosive effect. In effort to make sodium hypochlorite solutions stable some manufacturers market a corrosive product, and *vice versa* some non-corrosive preparations are unstable.—*R. E. Thompson.*

Corrosion in Boilers, Steam Engines, Steam Pipes and Apparatus, Its Occurrence and Prevention. Karl Kieper. Korrosion, 5: 13, 1930. From Chem. Abst., 24: 5277, November 10, 1930. Corrosion in boilers occurs at junctions of riveted plates and around rivets. It also occurs in neighborhood of feed pipe, where large amounts of dissolved gases are given off. No corrosion appears at end of boiler opposite the feed. It can be prevented by chemical means with lime, or gases may be removed from feed water by flashing under vacuum.—*R. E. Thompson.*

Improvements in the Methods of Biological Purification of Waste Waters. Aktieselskabet Dansk Gaerings Industri, Denmark, F. P. 651,682; Chim. et Indust., 1929, 22: 717. In method described, special bacterial cultures are used, purification, which takes place in series of basins, being most favoured by bacteria in the zoogloea state. Regeneration is accomplished by agitating the bacteria in vats of cold water in presence of an oxidising agent. The method is applicable for purification of water containing albumin, starch, cane sugar, or urea.—*M. H. Coblentz* (*Courtesy Water Pollution Research Board, Summary of Current Literature*).

The Neutralisation of Acid Waste Waters by Rock Carbonates. Noll, F. Gesund. Ing. Supplement, Series II, No. 7; Reviewed by Heilmann, Gesund,

Ing., 1929, 52: 786. Wastes containing sulphuric acid must be treated in as concentrated a condition as possible, but dilution is permissible with wastes containing nitric and hydrochloric acids. Naturally occurring calcium and magnesium carbonates are unsuitable for sulphuric acid removal. Lime in different forms will neutralize sulphuric acid and precipitate compounds of heavy metals. Shape and size of settling tanks are discussed. For treatment with limestone, hydrochloric and nitric acids must be separated from sulphuric acid. Use of limestone, part played by carbon dioxide gas, and plant required are described. The number of industries discharging acid water and importance of purification of rivers and sewers are dealt with.—*M. H. Coblentz (Courtesy Water Pollution Research Board, Summary of Current Literature).*

The Purification of Effluents from Coal Mining and Coal Washing. Reich, A. Gesund. Ing., 1929, 52: 776. Water pumped from coal mines contains in some cases only a high proportion of salts, but in other cases it is also acid. Mine waters from Upper Silesia carry into small Birawka river free sulphuric acid, ferric and ferrous sulphates, traces of nickel sulphate, and other compounds, rendering the water, analysis of which is given, acid, unsuitable for all domestic purposes, and harmful to fish life. Neutralization is not only economically infeasible, but would also cause formation of large quantities of sludge, which high water might carry down the river. To comply with Prussian Water Law of 1913, mine owners must so far purify their waste water that it will not cause nuisance and pollution. Purification of water pumped from mines themselves consists of neutralization, where necessary, and mechanical separation of solid matter. The settling tanks are large, shallow, and convenient for removal of sludge. Neutralization with milk of lime forms a light sludge which may reach the stream before settling; treatment with barium carbonate (witherite) is better. Coal-washing water is laden with fine coal particles mixed with clay and stones. Two to six hours settling time is necessary. Sludge is withdrawn either dry, or wet. Dry process is specially suitable, as coal sludge is heavy and forms firm mass which is often artificially drained by seepage pipes after supernatant water has been run off. Less tank space is required if sludge is withdrawn wet, but weight of the coal sludge and firmness of the mass cause difficulties in pumping processes. Plant for diluting the sludge and removing it by suction has, however, been found by the Emschergenossenschaft to work well. Dried sludge is mixed with waste coke from coke ovens and used mainly for boiler heating at the mines. Several processes for utilisation of coal sludge are briefly described.—*M. H. Coblentz (Courtesy Water Pollution Research Board, Summary of Current Literature).*

The Determination and Extraction of Phenol in the Effluents from Brown Coal Distillation. Rosin, P., and Just, H. Z. angew. Chem., 1929, 42: 965, 984, and 1002. Description of investigation carried out in order to find reliable method of extracting and determining phenol in waste waters from brown coal distillation. Process of Ullrich and Kather for extracting phenol by benzole-quinoline mixture and finding the bromine demand is very accurate for effluents from coke factories and gas works; but phenol in effluents from distillation of brown coal is extraordinarily complicated in composition, containing

cresols, pyrocatechols, and only a little carbolic acid. Series of experiments is described which showed that, taking bromine demand of phenols as 3 atoms of bromine to 1 molecule of phenol and the molecular weight of phenol as 109 (between that of cresol 108 and that of dihydroxybenzole 110), the quinoline-benzole method gave a "phenol-number" which expressed very accurately the number of grams of phenol per litre. Account is also given of behaviour of pyrocatechol, resorcinol, and hydroquinone during bromination. Fatty acids which might be present were found to have no bromine demand. As criterion for correctness of quinoline method, ether method of gravimetric analysis was tried. Less phenol was found than by quinoline method and, on bromination, bromine demand was also much less. Separation of this "raw phenol" from fatty acids by sodium bicarbonate and by sodium hydroxide raised the demand to 92.5 and 97 per cent, respectively, of that of pure phenol. Ether method is not suitable for coal distillation effluents. New gravimetric method of analysis is described. Solution was extracted with quinoline-benzole mixture and then with sodium hydroxide and neutral constituents were washed out with ether. Ether method was then followed and extraction of final ether accomplished by method used by Erdmann-Dolch in estimation of creosote in tar. Extraction is rapid and complete. Though fatty acids are not separated from phenol, pure phenol content can be accurately determined by dissolving in water and bromination. Extraction experiments with different washing media are then described. Small addition of quinoline adds greatly to the efficiency of benzole, but is too expensive for use in practice. Experiments with other media showed xylol to be slightly better than benzole, but other substances considerably worse. Mixtures of benzole with pyridine and aniline gave good results. Pyridine is dearer than aniline and less suitable, because of its solubility in water. High bromine values due to aniline addition can be prevented by washing phenolate lye with benzole. Results of large number of experiments with this mixture are given in tables and curves. Technical aniline oil was found to serve the purpose as well as analytical reagent grade. By application of counter-current principle, with repeated partial extractions 75 per cent phenol extraction was achieved with 25 percent (calculated on distillation water) of aniline-benzole mixture. Residual phenols in distillation water contained no carbolic acid. Advantages of this method over Emschergenossenschaft method for coke waste waters are discussed. Dissolved aniline with ammonia and benzole may be driven out of water by steam. Economic value of method depends largely on possibility of ammonia recovery.—*M. H. Coblentz* (*Courtesy Water Pollution Research Board, Summary of Current Literature*).

The Rhine, Its Purity and Its Flow. Foerderreuther. Gesund. Ing., 1929, **52**: 583. An account of the Rhine, its stability of flow, its drainage district and tributaries, its self-purification and bacterial content. Drainage area of river and its tributaries is 224,400 square kilometers.—*M. H. Coblentz* (*Courtesy Water Pollution Research Board, Summary of Current Literature*).

The Permissible Loading of a Stream with Town Sewage. Mahr. Tech. Gemeindebl., 1929, **32**: 203. The author deals with the composition and

volume of sewage and of rain water, respectively, and concludes that three forms of pollution may be taken as of almost equal importance: (1) undissolved matter in sewage, (2) dissolved and colloidal matter in sewage, and (3) polluting matter in rain water. First type may be treated by settling and second, by biological purification. Latter is expensive, and result almost equally satisfactory as regards condition of stream might be obtained by building clarification plant for rain water. Sketch and description of such a plant are given.—*M. H. Coblentz (Courtesy Water Pollution Research Board, Summary of Current Literature).*

The Heterogeneity of River Water. Dolgoff, G. I. Intern. Rev. ges. Hydrobiol. u. Hydrog., 1929, **22**: 371. Author discusses observations of numerous investigators in Germany, America, and Russia on effect of entrance of tributaries on the water of main stream and gives an account of investigations of distance required by tributaries to effect complete mixing with water of main stream, which were made at different points on the Volga, the Moskwa, the Suchona, the Kljasma, the Osuga, and the Sewernyj Donetz by electric conductivity measurements. Details of measurements and of differing physical and chemical conditions are given in each case. Laboratory experiments were also carried out under differing conditions of current with a model canal and tributary entering at right angles. Results are illustrated. Author emphasises importance of such studies in choice of position of water supply intakes and of sewage works outfalls.—*M. H. Coblentz (Courtesy Water Pollution Research Board, Summary of Current Literature).*

Mechanical Liming in Naturally Acid Streams. Reinecker, P. Z. f. Fischerei, 1929, **27**: 99; Wass. u. Abwass., 1929, **26**: 191. Author reports on proposed mechanical devices for liming naturally acid streams, or ponds, of pH as low as 3.87 and for improving water for fish. Two models are described, both of which contain rectangular frame, driving paddle-wheel, and machine (mill) itself, which is composed of covered vat holding from 2 to 3 hundredweights of lime, stirrer, valve for regulating the feed, and arrangement for agitating lime in vat. Machine is operated by water current. Too strong liming must be avoided. Expenses are small.—*M. H. Coblentz (Courtesy Water Pollution Research Board, Summary of Current Literature).*

Making Over a Municipal Water Works. C. N. Harrub. The American City, **46**: 4, 79–80, April, 1932. Extensive remodeling of Murfreesboro, Tenn., water works included replacement of two old boilers by new; new stack; removal of old pressure filters; enlargement and rebuilding of boiler and pump house, converting old filter room into generator room; installation of two generators; construction of filtration plant, with sedimentation and clear water basins; erection of new storage tank; and building of belt line of pipe around city to improve pressure. New filtration plant includes two sedimentation basins, four rapid sand filters, and million-gallon reinforced concrete clear water reservoir. With retention of former pumping equipment and installation of new, Murfreesboro can now boast of two complete plants, one steam and the other electrical, latter also in duplicate. Badly creviced limestone with

numerous solution channels was found at site of sedimentation basin and clear water reservoir, but solid rock was located by drilling holes to depth of 20 feet. Pits were then excavated at column sites, removing loose, or thin, rock down to 10-foot layer, and reservoir bottom redesigned to meet these conditions, carrying columns down to solid rock and placing girders under floor.—*Arthur P. Miller.*

Iron Removal without Filtration. E. T. ARCHER. The American City, **46**: 4, 82–84, April, 1932. Most of penal institutions of Kansas are located at Lansing, total population of which is 3400. Penitentiary supplied all water, condition of which is described as having been "terrible" and only $7000 was available for improvements. Carbon dioxide and iron were unsatisfactory and water was bacteriologically unsafe. It was decided to install equipment to secure (1) positive aëration with maximum carbon dioxide removal, with half the loss of head previously required, thereby gaining additional depth in reservoir of four feet; (2) accurate measuring and thorough mixing of lime and alum necessary to oxidize and flocculate the iron; and (3) improved sedimentation by preventing short-circuiting in settling basin. These ends were attained by means of Aer-O-Mix unit, dry-feed chemical machines, and rearrangement of settling basin. Results have even exceeded expectation, present system being, at least temporarily, satisfactory.—*Arthur P. Miller.*

Continuous Lime Slakers Feature Small Water-Softening Plant. H. F. WIEDEMAN. The American City, **46**: 6, 63–64, June, 1932. Water of Thomasville, Georgia, has 200 p.p.m. hardness, including 135 p.p.m. carbonate hardness and 65 p.p.m. non-carbonate. To soften this water to 68 p.p.m. hardness, lime-soda process was adopted. Use of quick lime effects saving of 25 to 30 percent as against hydrated lime, because of higher calcium oxide content, and was adopted. Continuous lime slakers were therefore installed. Plant also includes mechanically agitated mixing tanks where lime and soda ash are added, clarifier providing mechanical removal of sludge, carbonating chamber for addition of carbon dioxide gas, plain sedimentation basin, and filters. Carbon dioxide gas is obtained from power house stack and passed through a wet and a dry scrubber. Gas may be applied before final sedimentation and before filtration.—*Arthur P. Miller.*

The Handling of Unprofitable Water-Main Extensions. H. B. RICHARDS. The American City, **46**: 6, 67–68, June, 1932. There are three general types of non-productive water main extensions. (1) Mains run into virgin territory as part of real estate promotion scheme. Here it is proper to require owners to finance the work on some type of refunding agreement. (2) Mains run to supply number of scattered property owners whose own supplies are not satisfactory. Utility should here determine the investment it can reasonably make, dividing the balance up equitably among those consumers who are parties to agreement covering extension. (3) Main run to serve a single consumer who has purchased lot beyond existing facilities for purposes of economy. Such purchaser should be willing to divide his savings on real estate with utility in construction of necessarily unprofitable water line run to his property.—*Arthur P. Miller.*

The Lime-Soda-Ash Process of Water Softening. FRANK W. BOUSON. The American City, **46**: 7, 45–47, July, 1932. South Pittsburgh Water Co. serves territory south of Monongahela and Ohio Rivers with water softened to hardness of 100 p.p.m. Raw water, taken from Monongahela River, is well known for its acid qualities and hardness. Softening and carbonating process is described in considerable detail. New carbonation plant, utilizing carbon dioxide generated by burning natural gas, is being built. Sedimentation, filtration and chlorination take place following softening. Complete settling out prior to filtration of alumina naturally present in raw water is essential, to preclude its adherence to sand and gravel so closely as not to be removable by ordinary washing. Alumina accumulating in this way on filters would soon seriously affect their efficiency.—*Arthur P. Miller.*

When Customers Complain of the Quality of the Water, What Then? EDWARD C. TRAX. The American City, **46**: 7, 47–49, July, 1932. Writer discusses in interesting way method of handling customers' complaints. In McKeesport every complaint, whether justified, or unjustified, is investigated. Investigator goes directly to consumer's home, hears story and tests sample of water for hardness, alkalinity, chlorides, and the like. These tests are usually made on the premises, with portable testing set. Other samples are collected and report of results of tests, together with such explanations of cause of complaint as are possible is furnished to consumer. Assurance of safety of water is always given.—*Arthur P. Miller.*

Take the Water Works to the Fair. HARRY HARDINGE. The American City, **46**: 7, 49, July, 1932. Describing successful exhibition booth maintained by water department of Hillsboro, Ohio, at local fall festival.—*Arthur P. Miller.*

Sewer and Water Improvements Financed Chiefly by Civic Generosity. The American City, **46**: 7, 54–56, July, 1932. After deliberating 20 years, Millbrook, N. Y., decided to install both water and sewer systems. Millbrook is actually a network of country estates clustered about a few residential streets. Estates have had very little to gain by approving installation of water lines and sewers, because they are self-sustaining in these respects. However, summer residents took active interest in work and relieved citizens of built-up community from very heavy taxation to defray expense of work by making anonymous gifts and helping them to meet other financial obligations. This job is notable for generosity of estate owners who actually did not benefit at all from improvements. All work was done by one contractor. Source of water supply selected was infiltration system consisting of well with capacity of 25,000 gallons receiving water through its bottom and from two infiltration galleries at right angles to each other. Deep well pumps are used.—*Arthur P. Miller.*

Water Meters: Are They A Benefit? E. H. RUEHL. The American City, **46**: 7, 57–58, July, 1932. Advantages accruing to municipality upon installation of meters are set forth, as well as the few commonly alleged disadvantages. Questions of ownership and of location of meters and plan for installing 700

meters at rate of 100 per week in Bluefield, Va., are discussed.—*Arthur P. Miller.*

Pumps at Brantford Filtration Plant. Canadian Engineer, 62: 15–16. The $375,000 plant at Brantford, Ont., consists of six 1,000,000-gallon gravity rapid sand filters. Pumping equipment consists of 3 vertical, low-lift, centrifugal pumps, one of 4- and two of 6-m.g.d. capacity, which deliver raw water from suction well to mixing chamber and coagulation basins, and for main service supply, two 6- and one 4-m.g.d. horizontal units.—*R. H. Oppermann.*

Municipal Swimming Pool at Kitchener, Ont. E. G. Koyl. Canadian Engineer, 62: 9–10 and 52–53, April 5, 1932. Is $40,000 pool, 190 by 75 feet, equipped with three 72-inch diameter pressure filters, chlorinator, and hair and lint strainer. The 4-inch horizontal centrifugal circulating pump is directly connected to 25-h.p. motor. Soda ash and alum are fed automatically prior to filtration. Water is continuously circulated at rate of 21,000 gallons per hour, so that complete recirculation and refiltration takes place every twenty-four hours.—*R. H. Oppermann.*

Some Aspects of the Corrosion Problem. U. R. Evans. Engineer, 153: 3982, 504–506, May 6, 1932 and 3983, 532–533, May 13, 1932. James Forrest lecture to Institute of Civil Engineers, dealing with causes and principles of corrosion and its prevention, scale and oxide films, corrosion in liquids, pitting, and protection of iron and steel and of structural steelwork. It is incorrect to assume that corrosion occurs only in presence of acids; alkaline liquids may cause intense attack; and pure materials may suffer as much as, and sometimes more than, commercial product. Protective influence of calcium carbonate film upon water pipes, etc. varies considerably with physical character of the carbonate, and interaction with iron compounds often produces mixed deposit. Objection to free carbon dioxide is not that it is exceptionally corrosive, but that it prevents deposition of protective calcium carbonate.—*W. G. Carey.*

Corrosion of Iron and Steel. Anon. Water and Water Engineering, 34: 403, 224, May 20, 1932. Description of paint containing 80 per cent liquefied lead, which forms metallic film on iron and steel. It can be sprayed on and a coat of cellulose paint can be applied afterwards. Scraping, or rubbing, does not remove film and it is immune from atmospheric attack. Specimens of steel painted therewith withstood strongly corrosive moist atmosphere. —*W. G. Carey.*

Annual Distribution Conference of the American Gas Association, Birmingham, Ala., April 6–8, 1932. Determining the Performance of a Coating Without Disturbing a Gas Line. R. J. Kuhn. Welded 3- to 20-inch high pressure gas lines in New Orleans are susceptible to corrosion. Mains are coated with 15-pound asbestos felt spirally wound and dipped in hot asphalt. Electrical drainage provided consists of bonding the mains through one or more metallic connections to return circuits of electric railway system. Factors affecting electrical drainage of coated welded steel mains are imperfections in the coating,

such as scars, air pockets, and pin holes. It is essential to know the performance as regards electrical resistance of coating, in order to regulate properly potentials so as to overcome electrolysis, galvanic action, and soil corrosion. Three methods are used to measure this electrical resistance: (1) laboratory tests, (2) field tests, and (3) tests on buried nipples. Test is described on 2500 foot section of 12-inch line provided with flange type insulating joints at each end and with large size wire welded to pipe at time of construction and brought to surface for testing purposes. High value of 3.26 ohms was observed after 3 months; 2 months later it was 0.234 ohm; stable state was reached sometime later at 0.179 ohm. Electrical drainage has eliminated failures on lead water service pipes and similar results are indicated for iron and steel structures. **Report to the Subcommittee on Pipe Coatings and Corrosion on Effect of Soil Stress and Roots on Pipe Coatings.** ERICK LARSON. Experience of Long Island Lighting Co. is that under average conditions uncoated wrought iron pipe is good for 20 to 30 years and uncoated steel pipe in same territories for not quite so long. Correlation of corrosion and soil characteristics was found not to be conclusive. This work applied to distribution system where conditions warranted protection over entire area. After failure of cold application coatings, tar enamels of 160° m.p. were tried without wrapping and greater causes of faults were found to be soil stress and root penetrations, roots up to $\frac{1}{4}$-inch diameter growing through the enamel to the steel and emerging again sometimes 2 feet away. Observations led to use of higher melting point enamel which proved a little better. It is believed that roots will not enter enamel unless fine cracks have developed. Good wrappers give protection against soil stress, but wrapper must also resist chemical and bacteriological action. Wraps have now been in soil for several years remedying soil stress conditions, but it is unknown as yet whether they will do the same for root penetration.—*R. H. Oppermann.*